SUMMARY OF THE EFFECTS OF ONCE-THROUGH COOLING AT THE PALISADES NUCLEAR POWER PLANT

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Consumers Power Company

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Table of Contents

SUMMARY

GENERAL

Consumers Power Company of Jackson, Michigan initiated in 1968 a study to monitor the effects of once-through cooling on the biota of Lake Michigan in the vicinity of the Palisades Nuclear Power Plant. This developed into a seven year study, incorporating four preoperational years and three years after the plant began operations.

The power plant began operations at 20 percent of rated power on December 21, 1971. Allowing for periodic shutdowns, the plant reached 60 percent of power in August 1972, 85 percent in January 1973 and 100 percent on April 12, 1973. Due to mechanical problems, the plant was off-line from August 1973 until after the completion of the surveys a year later.

Preoperational lake studies were begun in May 1968 and continued four times a year (May, June, August and October) until October 1971. Lake sampling was conducted only twice in 1972 (June and October), but was returned to preoperational frequencies in 1973. Sampling occurred during two months, June and August, in 1974. An additional survey was scheduled in October 1974, but was abandoned due to adverse lake conditions. Surveys related more directly to plant operation were conducted more frequently during the period of once-through cooling.

The principal biological parameters measured during the study were benthos diversity and density; plankton species density, productivity and mortality; fish species abundance and the numbers impinged on the traveling screens of the power plant. Studies were also made of psammolittoral organisms inhabiting the shoreline and periphyton growth.

Temperature profiles were taken during sampling, and thermal plumes were mapped under various operating and lake conditions. Visual observations were made on the effects of the intake crib on fish movements, and transects by scuba divers observed the nature of the lake bottom, and whether attached growths were developing in the study area. The sediments from each station were analyzed for particle size and percent organic carbon on two occasions during the study period.

Consumers Power Company undertook the operational phase plankton productivity and mortality studies and fish impingement and nearshore distribution studies, and were involved in the scuba observations. These studies were made under the direct supervision of Dr. R. S. Benda, Biology Department, Aquinas College, Grand Rapids, Michigan. The Institute for Fisheries Research of the Michigan Department of Natural Resources studied the fish populations, and Beak Consultants studied the plankton, benthos, periphyton, psammon and sediments. Plume mapping was done by Consumers Power Company and Argonne National Laboratories. Temperatures were recorded by all investigators.

TEMPERATURE

Continuous temperature records of the Palisades Plant intake and discharge and the South Haven Water Treatment Plant were used to identify the temperature variations incurred during the study period. Thirty-six temperature surveys were conducted to delineate the characteristics of the thermal plume as it developed from the shoreline discharge. In addition, temperature data were collected during the biological surveys. The temperature rise through the plant varied from less than 5.6°C to about 15°C. The average plume size, as defined by attempting to delineate an isotherm at approximately 3°F (1.67°C) above ambient, was 231 acres (ranging from 17 to 870 acres). The majority of the plumes flowed in a northerly direction and occupied only the surface layers, although sinking plumes were observed on three occasions. Photographs taken during lake ice conditions document the relatively small area of melting caused by the discharge.

INTAKE CURRENT

Scuba divers measured current velocities on two separate occasions at the face of the intake crib, located 3,300 feet offshore. Velocities at the center of each face of the intake ranged from 0.69 to 0.95 ft/second, compared to a design average velocity of 0.5 ft/second.

SEDIMENT ANALYSIS

Sediment samples were collected in October 1971 and October 1973 throughout the sampling grid, and analyzed for percent organic carbon and particle size distribution. While some variability was notable, the mean percent organic carbon results for stations in less than 60 feet of water were less in 1973 than in 1971. Mean results were below 0.5 percent in 1973 compared to mean values greater than 1.0 percent in 1971.

Particle size analysis showed a predominance between 0.074 mm and 0.297 mm (fine to medium sand) although variability outside of this range and between stations was common. Comparison of the results from 1973 and 1971 showed an overall higher proportion of finer materials in 1973.

PLANKTON

Lake plankton were compared throughout the study period by sampling at each station and determining packed cell volume. Detailed identifications were made during the period of once-through cooling. The effects of condenser passage on the productivity and mortality rates were studied from May 1972 to October 1973.

Substantial variations in plankton standing crop occurred between 1968 and 1974 and did not appear to be related to plant start-up. Significant differences in the packed cell volumes at control stations and those close to the discharge had already occurred between August 1968 and May 1971. Only one sampling period, June 1972, had a plume present where station surface

temperatures were maintained significantly above ambient. The plume extended south from the plant and standing crops of plankton at stations affected by the plume were lower than at stations outside the plume's influence.

During all post-operational surveys, diatoms (Bacillariophyceae) dominated the phytoplankton. Tabellaria, Asterionella, Fragilaria, Cyclotella, Melosira and Synedra were all dominant genera at one time or another. Other common genera were Navicula (Bacillariophyceae) Rhizosolenia, Scenedesmus and Pediastrum (Chlorophyta) and Dinobryon (Chrysophyta). The blue-green (Cyanophyta), commonly represented by the genera Oscillatoria, formed only a small part of the plankton community.

The total standing crop of phytoplankton was higher in June 1974 than at any time since counting began in 1972. This high standing crop corresponded with a high packed cell volume.

Studies on the effects of condenser passage indicated that, with no heat added, phytoplankton productivity varied between an average loss of 35.6 percent and an average gain of 35.4 percent. With the introduction of heat, the change in productivity varied from an average loss of 47.9 percent to an average gain of 36.2 percent. When all the results were examined, it appeared that mechanical stress caused approximately one-half the decrease in primary productivity.

The most abundant and consistently appearing zooplankton groups in the cooling water were the cyclopoid and calanoid copepods and the Bosmina cladocerans. The copepods appeared in every sample, but Bosmina appeared primarily in the summer months and in large numbers at that time. The dominant forms were Bosmina longirostris, Diaptomus, Limnocalanus, Asplanchna, and Daphnia retrocurva. Bosmina (Cladocera) were the least affected by the heated discharge, with 6.1 percent difference between the mortality measured from the intake and discharge water. Calanoid copepods were most affected with an average difference in mortality between discharge and intake samples of 14.9 percent. The mortality when a nonheated discharge was present was very similar for most of the zooplankters and lower than that in the heated discharge. Mortality ranged as high as 90 percent when discharge temperatures were between 32° to 38°C. Mechanical damage particularly affected the larger zooplankters.

The zooplankton standing crop was dominated numerically by Keratella cochlearis and Polyarthra spp. Kellicottia spp and Keratella quadrata were also common. The cladoceran fraction was dominated by Bosmina spp.

The zooplankton density in June 1974, similar to the phytoplankton standing crop, was greater than had occurred in June of the previous two years.

ATTACHED FILAMENTOUS ALGAE AND ROOTED AQUATICS

Attempts to monitor the growth of periphyton on submerged artificial substrata during the preoperational period were abandoned because of poor success in maintaining and recovering samplers. It was not expected that attached growth would be evident, because of the lack of suitable substrate

along the shoreline, and subjective observations were substituted for controlled experiments.

Observations were made of unusual amounts of filamentous algae in seine nets used during June 1971 and on gill nets in August 1971, but there was no evidence that the material originated in the vicinity of the plant. The shore area, except for man-made structures and driftwood, was observed to be generally free of filamentous algae and rooted aquatic growth.

PSAMMOLITTORAL ORGANISMS

The study to determine whether psammolittoral organisms would be affected by plumes during periods of onshore winds was undertaken in June and October, 1972 and 1973. Total counts of organisms indicated that numbers were highest in the cores taken above the waterline, where greatest diurnal fluctuations in temperature occurred. The highest counts were in June 1972 and October 1973. The origin of the psammon was both planktonic and epipelic; the dominant organisms which could be identified were diatoms, other algae, protozoans, rotifers, oligochaetes and nematodes. Comparison of organism density at the various stations did not reveal any relationships with distance from the plant or any plant related abnormal variability.

BENTHOS

In order to analyze the benthos and plankton in a convenient, statistical manner, bivariate control charts were constructed for certain groups of stations. During initial analysis, it was noted that the dominant groups of benthic organisms were depth-dependent. Stations at similar depths, within and without the probable influence of the plume, were grouped for the construction of the charts. Both diversity and density of benthos were displayed this way.

In analyzing the benthic macroinvertebrates by the bivariate control chart method, the data indicated that significant changes in density occurred at a number of the stations on the survey grid. Some of the stations, but not all where changes had occurred, were close enough to the discharge to be affected by the plume. The Mann-Whitney test which does not make any assumptions about the normality of the population distributions, was used to determine whether there had been any statistically significant increases or decreases in the post-operational population densities of individual organisms.

The outermost grid stations which were at depths greater than 50 feet had one significant change in density, that of the oligochaetes in August 1973. Study of this group of stations in October 1973 showed that the densities had returned to lie within the limits of the normal fluctuations that could be expected. The deepest stations were not studied in 1974 as they were not considered critical when correlating effects with the thermal plume. Using the Mann-Whitney analysis, six of the deepest stations, C-2, G-2, C-5, F-5, CN1 and CS1, had significant changes in the density of certain organisms.

Most of the significant changes illustrated by the control charts occurred at the 30 to 50 foot depths. Sphaeriids showed changes in October 1973 and June 1974 and chironomids in June 1973 and 1974 and August 1974. Of the inner and outer stations represented by these charts, C-1, F-1 H-2 and CN2 had significant increases or decreases as determined by the Mann-Whitney test.

Only one statistically significant change was demonstrated on the control charts for the 20 to 30 foot depth level. This was on the chart for stations southwest of the discharge, and represented oligochaetes for October. Density changes occurred in both 1972 and 1973. The Mann-Whitney test demonstrated significant changes at F/2, G/2, H-1, B-1, C/2, D/2, A-2 and I-5, all represented on this group of charts.

The benthic diversity indices were calculated for the June and October surveys. The diversity indices for October were all within expected limits but the 1972 and 1973 June diversities showed changes beyond the expected fluctuations at both inner and outer stations. A significant change occurred only in June 1974. Two groups of stations were involved, the first at 20 to 30 foot depth southwest of the discharge where the diversity decreased. The other stations where changes occurred were at 30 to 50 feet, the inner stations lying northwest and southwest on the C and F lines, respectively. The June diversity indices had been higher since 1972 and lay beyond the control limits of the inner stations.

Using the Mann-Whitney test, the following individual organisms showed significant changes in population density between pre- and post-operational years.

Eurycercus (Cladocera) increased in density at four 1/2 mile stations and one station at 1, 2 and 5 miles from the discharge on lines both north and south on the survey grid.

Amnicola was the only gastropod to have significant increases in density. These occurred at stations between 1 and 2 miles southwest of the discharge. Both Amnicola and Valvata (Gastropoda) showed significant decreases at some of the stations, Amnicola, 1 mile northwest and 5 miles south and Valvata 2 miles north and at the north control near South Haven.

Three chironomid genera showed numbers that were significantly greater at six of the stations. Cladotanytarsus showed significant increases at two 1/2 mile stations west of the discharge, a 1 mile station southwest of the discharge and at the north control. Cryptochironomus increased at a station two miles to the northwest and Paracladopelma showed significant increases one mile north of the discharge. Four genera had significant decreases in density. Chironomus decreased significantly at stations 1/2 mile west, one mile southwest and two miles north and also at the south control near Benton Harbor, where Procladius also decreased in density. Cryptochironomus decreased at stations two and five miles south of the discharge and Heterotrissocladius decreased at a station five miles west from the plant.

One oligochaete, Potamothrix moldaviensis increased in density at one 1/2 mile station and one 1 mile station southwest of the discharge.

Sphaeriids exhibited increases and decreases in density at a number of stations. Pisidium increased at two 5 mile stations and decreased in density at one 1/2 mile station, one 1 mile station (all northwest of the plant) and three 2 mile stations (lying north and south) and a south 5 mile station. Pisidium also decreased at the deeper of the south controls. Sphaerium increased in density at one station lying two miles southwest of the discharge and decreased in density at two stations, one 5 miles northwest and at the deeper south control.

Pontoporeia hoyi (Amphipoda), which was found in larger numbers at the deeper stations, showed a significant increase in density at one station lying two miles southwest of the discharge in 60 feet of water. It decreased at three stations; the 70 foot south control and a five mile station south of the discharge (28 feet) and a two mile station (23 feet) north of the discharge.

A few organisms appeared for the first time at some of the stations after the plant began operations. Cladotanytarsus (Chironomidae) appeared in the post-operational period at D/2, F/2 and CN2. Paracladopelma, also a chironomid, appeared at A-1 during the post-operational period. Amnicola (Gastropoda) appeared at F-2. One organism disappeared from the samples, Procladius (Chironomidae) was not sampled at CS1 (17 miles south of Palisades) after the pre-operational period.

Overall, there were a larger number of significant increases in the density (20) of individual organisms at the sampling stations situated within one mile of the discharge, than at stations more than one mile distant (9).

Significant density decreases occurred for eight macroinvertebrates at stations one mile or closer to the discharge and 22 occurred at stations situated beyond one mile.

The planktonic forms, Cladocera and Ostracoda, were responsible for half of the significant increases at the inner stations (within one mile). Very few significant changes occurred in the populations of larger-sized crustaceans.

Changes, both significant increases and decreases, occurred scattered over the whole grid and at both north and south control stations. There were more density increases due west of the plant, but increases were also recorded at stations located northwest and southwest of the discharge. Decreases, apart from those at four of the deeper stations, H-2, C-2, C-5 and F-5, seemed to occur at the shallowest stations both north and south of the discharge, and were probably related to physical factors such as an unstable environment caused by rough water. No changes were of very high magnitude and density remained within control limits for the shallow water groups of stations.

FISH

A total of fifty-seven (57) species of fish was sampled, and the most common ones are discussed individually in the report. The same group of fish constituted the bulk of the catch at Cook, Palisades and Ludington, with some differences in proportion. Major species collected by gill net at Palisades included alewife (53.3%), yellow perch (40.1%), longnose sucker (3.1%) and white sucker (1.2%). The smaller species would have figured more prominently in the Palisades gill net data had smaller mesh size been used. Trawling and seining results indicated some species were attracted to the area when a heated discharge occurred, notably alewives, whereas other species indicated a negative reaction to the heated water.

Statistical treatment of data collected by the Institute for Fisheries Research did not indicate a significant change in abundance of any of the prominent species after the introduction of a thermal discharge in 1972. However, catches of major species, except the spottail shiner, did decline somewhat in 1973. The spawning period for about 1/3 of the perch collected was advanced by approximately three (3) weeks in 1973.

Impingement of fish on the plant traveling screens was monitored beginning in early 1972. A total of 653,890 fish were recorded as being impinged during the study period. Species most commonly impinged during once-through cooling operation were: alewife (58.6%), slimy sculpin (27.5%), spottail shiner (7.2%) and perch (4.2%). Relatively few game fish were impinged, with perch being the exception. In most cases (especially alewives, perch, smelt), the heaviest losses due to impingement were related to seasonal movements, particularly spawning migrations. Data indicate that no serious losses were occurring due to egg or larvae intake.

INTERACTIONS WITH FOOD WEB

The food web is by its very nature a complex system with interplay between each major component, primarily plankton, benthos and fish. In the Palisades Plant situation, additional factors had to be taken into account. These were the passage of cooling water with entrained organisms through the condensers, impingement of fish on the traveling screens and the discharge of heated water into the lake.

Plankton densities were affected in a variety of ways. The phytoplankton diversity was not altered, but zooplankton and phytoplankton densities changed according to plant effects. Mortality was lower when there was no heat, though mechanical stress had relatively significant effects.

Very little is known on how the zooplankton utilize phytoplankton as food, so the effects of condenser passage on the algal component used as food can only be hypothesized. Some zooplankton are detritivores, others are omnivorous and others active predators. The larger forms of the latter actively compete with larval or planktivorous fish.

Some of the benthic macroinvertebrates exhibited significant decreases or increases in density, but at stations scattered over the whole survey area, so no one location showed a change liable to affect the fish populations.

Perch, one of the dominant species of fish near Palisades, showed an advance in spawning time in 1973. The benthos during the time that the young fish would be actively seeking them for food were nearly as abundant as they would be slightly later in the year in which perch young are normally present. In the case of perch, and of course other fish, the power plant was increasing the temperature of the habitat and also competing for food by entrainment in the intake water of possible food organisms, both plankton and fish.

Other fish important to the fishery near Palisades would benefit from the increased densities and diversities of benthos which had been noted in the Palisades area, though a few decreases also occurred.

Loss of fish impinged on the traveling screens, of course, represents a direct removal of biological material from the lake. The impinged fish however, were both predators and forage fish, so more than one component of the food web was affected.

On the whole, the operation of the Palisades Plant with the once-through cooling system has not been shown to have any large detrimental impact on the local food web or on the overall populations of the lake.

INTRODUCTION

Consumers Power Company, in March 1967, began the construction of the Palisades Nuclear Power Plant, located on the east shore of Lake Michigan, about five miles south of South Haven, Michigan.

An environmental survey program was initiated in 1968 in response to concerns expressed about the effects of the discharge of heated effluents by various regulatory agencies, and with regard to standards being developed by the Michigan Water Resources Commission. Also, the Company was under commitment that, should the effects of the discharge on the aquatic biota prove significant, corrective measures would be taken. Allowing for periodic shutdowns, operations were begun in December 1971, at 20 percent of rated power, and were gradually increased to 60 percent in August 1972, 85 percent in January 1973, and 100 percent of full power (700 MWe) on April 12, 1973. The plant was shut down due to various operational problems in August 1973, and remained off-line for the rest of the study period. Events which will not be discussed here resulted in the construction of cooling towers for this plant which, after 1973, provided a closed cycle cooling system instead of once-through cooling.

A heated plume dissipates in the top layers of water for most of the year, enabling much of the heat to be transferred to the atmosphere. Asbury(1) calculated lake-wide effects of man-made thermal discharges on Lake Michigan. The annual average increase in water surface temperature due to thermal discharges in 1969 was calculated to be a maximum of 0.011°F, and projections for 1975 were 0.019°F. More significant effects than these suggested by overall rises would be anticipated in the inshore waters, close to the sources of heated dishcarges.

Lake Michigan is generally classified as an oligotrophic lake (poor in nutrients) with localized areas of enrichment(2), but it has been shown to be aging (undergoing eutrophication) by the addition of nutrients, especially in the areas of high population. Concern has been expressed that the addition of heat may cause conditions suitable for nuisance algal growth. The area near Palisades is not heavily populated, unlike the far south end of the lake, but there is a possibility that this region of the lake is becoming enriched more quickly than would be expected, and the addition of heated water might accelerate the occurrence of changes in the aquatic biota.

Prior to the initiation of the study, a program objective was established which was to determine the area of influence of the heated discharge and its impact on the biota of Lake Michigan. Those involved in the planning were environmental specialists from The University of Michigan, Michigan State agencies, Beak Consultants and Consumers Power Company. The program which was finally approved consisted of three phases:

1. Preoperational surveys of the benthos, plankton and fish to obtain a knowledge of the state of the lake, both in the vicinity of the plant and in areas away from any possible influence of the thermal plume.

2. Postoperational mapping of the thermal plumes.

3. Postoperational surveys of the benthos, plankton and fish to determine the thermal influence, if any, on the biota.

Beak Consultants Limited were retained to carry out the benthos and plankton portions of Phases 1 and 3, in cooperation with the Institute for Fisheries Research of the State of Michigan Department of Natural Resources, who would carry out the fish sampling. Consumers Power Company staff were to provide mapping of the thermal plume, as well as miscellaneous biological surveys directly related to plant operation. Phase 1 was begun in May 1968, with major surveys to be conducted in May, June, August and October of each year. Some modifications in this schedule were agreed to in later years.

The original plan was for two preoperational years and three postoperational years but, due to delays in plant start-up, data for four preoperational years were obtained. This formed a baseline against which postoperational data were compared to determine effects of the heated discharge on the biota of the area.

A special study was begun in 1972 to determine whether psammolittoral organisms could be significantly affected by elevated temperatures during times of onshore winds and currents. Psammon, microscopic organisms inhabiting the interstitial spaces of sand at the shoreline, were sampled four times during 1972 and 1973, in June and October of each year.

Special studies were also planned during the period of operation to investigate the effects of chlorination of the circulating water system on fish, plankton and psammolittoral organisms. Inasmuch as there was no chlorination of the circulating water system during the period of once-through cooling operation, there is no further mention of this phase of the study in this report.

In the presentation of results, emphasis is placed, where applicable, on graphical and/or statistical treatment of the data. Diversity indices for benthos were used and bivariate control charts developed for stations of similar depth. Significant changes in density for individual benthic species were also determined. The control charts permitted rapid evaluation of new data as they were generated, and displayed the results in a graphic and readily comprehensible form.

STUDY AREA DESCRIPTION

The shoreline on which the Palisades Plant is located is regular along the length of the study area, without large indentations. It is of the basic "high sand dunes" type, 30 feet or higher, described by Carlson[3], and is subject to erosion by wind and water.

The fan-shaped sampling grid shown in Figure I-1 was established for benthos and plankton samples (similar to that proposed by Garton and Harkins[4]) and was composed of nine lines radiating from the Palisades Plant and four concentric semicircles with radii of 0.5, 1, 2, and 5 miles. Initially, 21 sampling stations were selected on this grid, but the number was altered to include or exclude stations as experience was gained during the four preoperational years (Table I-1). Control stations outside the grid were set up near South Haven, seven miles north, and near Benton Harbor, 16 miles south of the Palisades Plant. Sampling stations for the fish collections and miscellaneous biological surveys are identified in the sections in which they are discussed.

Analysis of the sediments indicated that they consisted mostly of a fine to medium sand with occasional small amounts of mud and detritus. While not documented, it was observed by field biologists that wave action altered the stratification of the sands. After storms, the fine particles were always in the upper stratum, but during calm weather this varied, indicating a very mobile lake bottom.

Depths of the stations gradually increase lakewards, the deepest stations being 98 feet, five miles offshore.

Lake currents are reported to flow parallel to the shoreline 54 percent of the time due to southwest or northwest winds. At other times, the flow is offshore or calm[5].

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Table I-1: Sampling stations, dates, and depths 1968 to 1974

STATION	NORMAL DEPTH (ft.)	1968				1969				1970				1971			
		May 14 to 18	June 24 to 29	Aug. 28 to 29	Oct. 15 to 16	May 12 to 14	June 24 to 27	Aug. 25 to 27	Oct. 15, & 28	May 11,14 June 4,5	June 23 to 26	Aug. 25 to 27	Oct. 15, and 16	May 11, and 13	June 21 to 25	Aug. 23, and 24	Oct. 19, and 20
A-1	15					*	*	*	*	*	*	*	*	*	*	*	*
A-2	23					*	*	*	*	*	*	*	*	*	*	*	*
A-5	40					*	*	*	*	*	*	*	*	*	*	*	*
B-1	25	NS	NS	NS		*	*		*	*	*	*	*		*	*	*
B/2	15				NS	*	*		*	*	*	*	*		*	*	*
B/4	11	NS	NS	NS	NS	NS	*	*	NS	*	*	*	*	NS	NS	NS	NS
C-1	37	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*
C-2	50	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*
C-5	98	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*
C/2	23	NS	NS	NS	NS	*	*	*	*	*	*	*	*		*	*	*
CN1	70	*	*	*	*	*	*	*	*	*		*	*		*	*	*
CN2	35					*	*	*	*	*		*	*		*	*	*
CS1	70	*	*	*	*	NS	NS	*	*	*	*	*	*	*	*	*	*
CS2	35					NS	NS	*	*	*	*	*	*	*	*	*	*
D/2	23					*	NS	NS	*	*	*	*	*	*	*	*	*
E/2	24	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	*	NS	*
E/4	11	NS	NS	NS	NS	NS	*	*	NS	*	*	*	*	*	*	NS	NS

NS - Not Sampled
*   Plankton sampled also

Table I-1: (continued)

STATION	NORMAL DEPTH (ft.)	1968				1969				1970				1971			
		May 14 to 18	June 24 to 29	Aug. 28 to 29	Oct. 15 to 16	May 12 to 14	June 24 to 27	Aug. 25 to 27	Oct. 15, & 28	May 11,14 June 4,5	June 23 to 26	Aug. 25 to 27	Oct. 15, and 16	May 11, and 13	June 21 to 25	Aug. 23, and 24	Oct. 19, and 20
F-1	40	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
F-2	50	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
F-5	95	*	*	*	*			*	*	*	*	*	*	*	*	*	*
F/2	25					*	*	*	*	*	*	*	*	*	*	*	*
G-2	60	*	*	*	*	*	*	*	*	*	NS	*	*	*	*	*	*
G-5	90	*	*	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G/2	25	NS	NS	NS	NS	*	*	*	*	*	*	*	*	*	*	*	*
H-1	25					*	*	*	*	*	*	*	*	*	*	*	*
H-2	45	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
H-5	57	*	*	*	*		NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
H/2	15					*	*	*	*	*	*	*	*	*	*	*	*
H/4	5	NS	NS	NS	NS	NS	*	*	NS	*	*	*	*	NS	"	NS	NS
I-1	13					*	*	*	*	*	*	*	*	*	*	*	*
I-2	13					*	*	*	*	*	*	*	*	*	*	*	*
I-5	28					*	*	*	*	*		*	*	*	*	*	*
500	9	NS	NS	NS		NS	NS	NS	NS		*	*		NS	NS	NS	NS

NS - Not Sampled
* Plankton sampled also

Table I-1: (continued)

STATION	NOMINAL DEPTH (ft.)	1972 June 19 to 27	1972 Oct. 9 to 13	1973 May 14 to 15	1973 June 14 to 18	1973 Aug. 21 to 22	1973 Oct. 8 to 10	1974 June 12 to 13	1974 Aug. 12 to 14
A-1	15	*	*	*	*	*	*	NS	NS
A-1	10	NS		*	*			NS	NS
A-2	23	*	*	*	*	*	*	*	*
A-2	10	NS		*				NS	NS
A-5	40	*	*	*	*	*	*	*	*
A-5	20	NS	*	*	*	*	*	NS	NS
A-5	10	NS	*	*				NS	NS
B-1	25	*	*	*	*	*	*	*	*
B/2	15	*	*	*	*	*	*	NS	NS
B/4	11	*	*	*	*	*	*	NS	NS
C-1	37	*	*	*	*	*	*	*	*
C-2	50	*	*	*	*	*	*	NS	NS
C-5	98	*	*	*	*	*	*	NS	NS
C/2	23	*	*	*	*	*	*	*	*
CN1	70	*	*	*	*	*	*	NS	NS
CN2	35	*	*	*	*	*	*	*	*
CS1	70	*	*	*	*	*	*	NS	NS
CS2	35	*	*	*	*	*	*	*	*
D/2	23	*	*	*	*	*	*	*	*
E/2	24	*	*	*	*	*	*	NS	NS
E/4	11	*	*	*	*	*	*	NS	NS
CN	20	*			*	*	*	NS	NS
CN	10	NS	NS					NS	NS
CN3	20	*		NS	NS	NS	NS	NS	NS
CS	20	*	*	NS	*	*	*	NS	NS
CS	10	NS		NS				NS	NS

NS - Not Sampled

Table I-1: (continued)

STATION	NOMINAL DEPTH (ft.)	1972 June 19 to 27	1972 Oct. 9 to 13	1973 May 14 to 15	1973 June 14 to 18	1973 Aug. 21 to 22	1973 Oct. 8 to 10	1974 June 12 to 13	1974 Aug. 25 to 27
F-1	40	*	*	*	*	*	*	*	*
F-2	50	*	*	*	*	*	*	NS	NS
F-5	95	*	*	*	*	*	*	NS	NS
F/2	25	*	*	*	*	*	*	*	*
G-2	60	*	*	*	*	*	*	NS	NS
G-5	90	NS	NS	NS	NS	NS	NS	NS	NS
G/2	25	*	*	*	*	*	*	*	*
H-1	25	*	*	*	*	*	*	*	*
H-2	45	*	*	*	*	*	*	*	*
H-5	57	NS	NS	NS	NS	NS	NS	NS	NS
H/2	15	*	*	*	*	*	*	NS	NS
H/4	5	*	*	*	*	*	*	NS	NS
I-1	13	*	*	*	*	*	*	NS	NS
I-2	13	*	*	*	*	*	*	NS	NS
I-5	28	*	*	*	*	*	*	*	*
I-5	20	NS		*	*	*	*	NS	NS
I-5	10	NS		*	*	*	*	NS	NS
500	9	NS	NS	NS	NS	NS	NS	NS	NS

NS - Not Sampled
* - Plankton sampled also

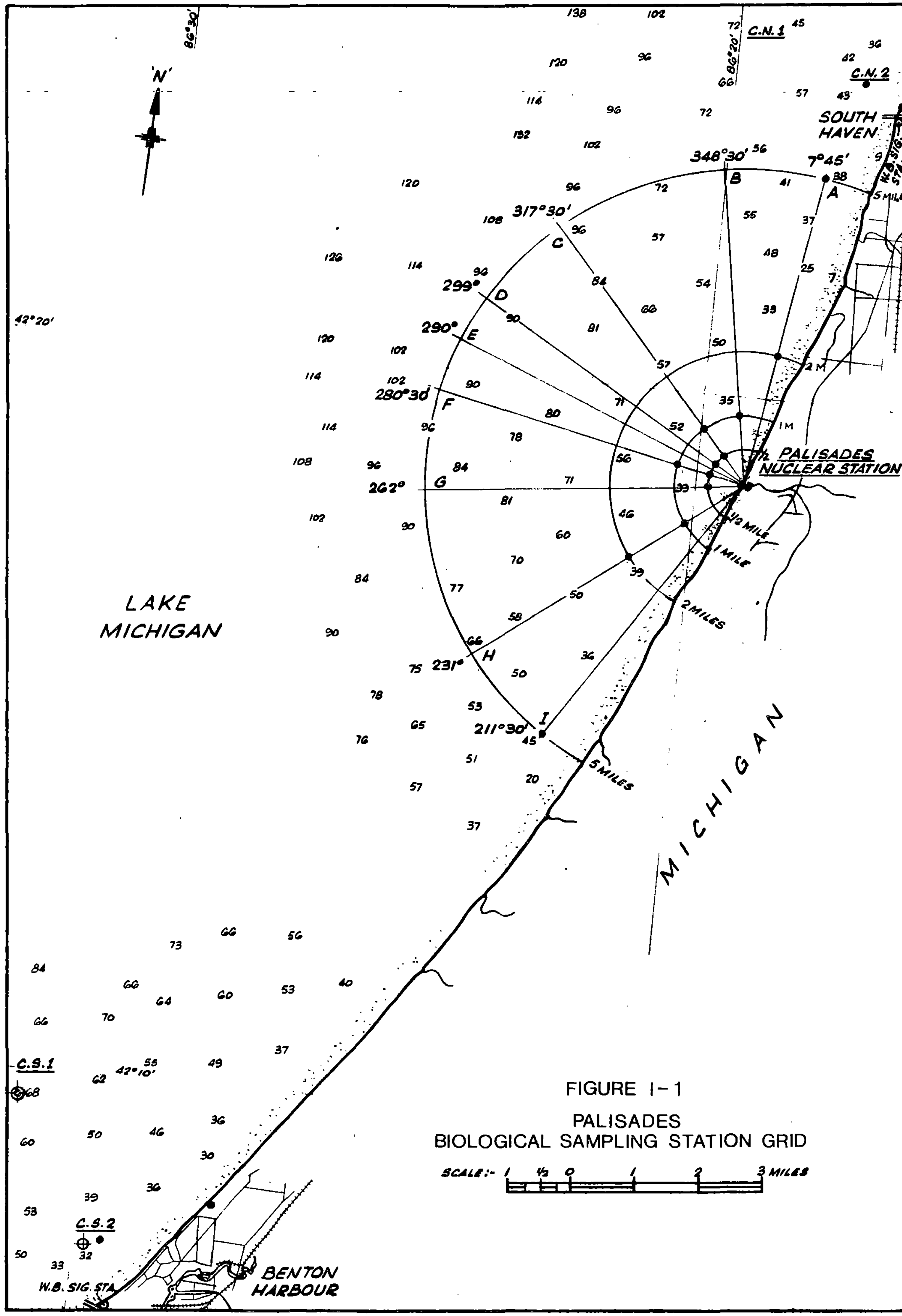

FIGURE I-1

PALISADES
BIOLOGICAL SAMPLING STATION GRID

FIELD AND LABORATORY METHODS

Station Location

To enable the survey boat to locate and remain on station, guide lights, corresponding to each radius of the grid, were mounted on the roof of the turbine building. A telurometer was initially used in conjunction with the lights, but during the majority of the surveys, the lights combined with a depth recorder and shoreline landmarks were used.

Temperature profiles were taken at the time of benthos and plankton sampling at each station. The temperature was recorded at the surface and five-foot depth intervals using a temperature probe Model 425F, Yellow Springs Instrument Company.

Benthos

Since it is obviously impossible to count all the benthos in a section of lake bottom, a close estimate of the natural populations of organisms may be obtained by collecting adequate numbers of representative samples. Samples of the bottom, together with contained animals, were obtained by means of a Ponar grab, which cuts out 0.54 square foot of bottom material to a depth of 2 to 6 inches depending on sediment texture. The bottom samples were washed using a US seine #30 to remove extraneous sediments, preserved with neutralized five percent formalin, and returned to the laboratory for processing.

In order to insure sampling reliability, a number of replicate samples were procured from each station on the fixed sampling grid laid out to cover the area that might be affected. In addition, a few control points were established, well removed from the source of heated effluent, to help determine the possible influence of other water users in the area. Initially, six samples were taken at each station, but this was reduced to three in 1969, when statistically justified on the basis of population means and diversity.

Samples were taken four times a year in the months of May, June, August and October, during 1968 through 1971. The number of sampling stations was increased for the postoperational surveys as a result of recommendations of the Atomic Energy Commission staff. Additional stations were included at 20- and 10-foot depths along the A and I lines north and south of the plant, and at the north and south controls.

Sampling frequency was reduced to twice in 1972, June and October, but was returned to the preoperational frequencies in 1973.

The 1974 survey for benthos and plankton was smaller in scope than the full scale surveys of previous years. Only stations where changes in population densities had been indicated, by use of the bivariate control charts, were sampled, and only the organisms involved in the changes were studied.

The macroinvertebrates were sorted from the sample residues, classified to major taxonomic groups and counted. Initially, one replicate from each station was selected for detailed identification for May, June, August and October. From 1969 onward, only June and October samples were identified in detail. In 1972, it was decided to identify three replicates from the June and October surveys to include 1968 onward, in order to offer the greatest experimental precision and highest confidence.

Some organisms, oligochaetes and amphipods, were examined to determine whether a biomass change had accompanied a change in density. The whole sample or up to a maximum of 50 individuals each of oligochaetes (complete individuals) and amphipods from selected samples were examined. Excess water was removed by filter paper and the organisms weighed to constant (wet) weight on a Mettler electric balance.

Plankton

Plankton samples were obtained by passing 40 liters of lake water through a Wisconsin plankton net. Initially, water samples were taken by means of an 8 liter packed cell volume (PCV) sampler. On later surveys, samples were collected by pumping 40 liters of water from three discrete depths (5, 10 and 15 feet) through a #25 Wisconsin plankton net suspended over the ship's side. Beginning in May 1969, plankton samples were obtained at each station by pumping 80 liters over a vertical haul. The calibrated intake hose was initially lowered to the desired depth, usually 15 feet, and the system flushed. The hose was gradually raised to the 5-foot depth during pumping so that the sample represented plankton present in a 10-foot stratum. Each sample was preserved with five percent formalin in a labeled dark glass bottle and returned to the laboratory for processing. Samples were taken at the same time as benthos samples at selected stations.

To obtain the PCV, the samples were centrifuged for five minutes at 3,000 r/min in 40 ml tubes, transferred to 15 ml graduated tubes, centrifuged for a further five minutes at 3,000 r/min and the PCV read to the nearest 0.01 ml.

For detailed analysis, 0.1 ml subsamples were taken from the original for examination. Each subsample was examined for zooplankton by scanning at 100x magnification. Three subsamples were scanned, the organisms were identified to genus, and the number of each per liter calculated.

The phytoplankton were identified at 100x magnification and enumerated by counting three fields in each of the three subsamples. A conversion factor was used to determine the numbers per liter.

Periphyton

Six periphyton samplers constructed of Plexiglas (5 x 15 x 0.6 cm) were suspended from a T-shaped bar embedded in concrete. One set was installed in 15 feet of water at each of three locations (the north and south

plant boundaries and opposite the outfall) on six separate occasions: May-June 1968; May-June and July-August 1969; June and August-October 1970; August-October 1971. After exposure for a period of 4 to 6 weeks, retrieval was attempted but only with moderate success. The plates were placed in five percent formalin and returned to the laboratory for processing. This program was discontinued before the plant became operational because of the extreme difficulty in maintaining and retrieving samplers and the limited amount of useful data.

The samples were treated in two separate ways. In 1968, the periphyton were scraped from the plates, extracted with acetone and the amount of chlorophyll present was determined by means of a Beckman spectrophotometer. In subsequent years, because of partial bleaching by the formalin, the dry weight was determined by filtering through preweighed filters and drying in an oven to constant weight. The results were expressed as weight per unit area.

Psammolittoral Organisms

The psammon were sampled by means of a Plexiglas corer with a cross-sectional area of 10 sq cm. It was approximately 20 cm in length and marked off in centimeters at one end.[1,2]

To take a sample, the corer was thrust vertically into the sand to a depth of about 10 cm. The tube was corked at the top and then carefully removed and a plunger inserted into the bottom. The cork was removed and any water was sucked off, as this could disturb the sand during manipulation of the core. The core of sand was pushed out of the upper end and slices 2 cm thick were cut off with a knife into containers. The cores were preserved with a saturated solution of glycerine (40 percent) in 4 percent formalin.

Nine cores, three taken two feet up the shore from the waterline, three at the waterline, and three at two foot water depth, were taken at each of 12 stations situated along the beach north and south of the plant discharge.

The stations were located opposite the 1, 2 and 5 mile stations on grid Lines A and I, opposite the north and south control stations, at the north and south plant boundaries and 1/2 mile north and south of the discharge. With a few exceptions, the stations were sampled in June and October of 1972 and 1973.

The psammolittoral organisms were washed from the sand by bubbling air through the sand and water for three minutes and then centrifuging the supernatant liquid. This was repeated three times for each sample. The organisms were concentrated and then counted by subsampling. Three subsamples were taken from each core sample, and then each subsample was sampled three times giving a total of nine whole grid field counts. The organisms in the grid field of a micrometer eyepiece were counted using a 0.25 objective and a 10x eyepiece. A conversion factor was used to determine the number per 10 ml sand.

Detailed identification was done of organisms in cores from sites A/2, A-1, A-5, North Control, North Boundary, I/2 and I-1, in June 1972, June 1973 and October 1973. Rough weather prevented complete sampling in October 1972 with detailed identification done on A-1, North Boundary, South Boundary, North Control and from near the plant discharge.

Sediment Analysis

One gross sediment sample was collected at each benthos station in October 1971 and 1973 by means of the power grab and returned without preservation to the laboratory.

Sediment samples were analyzed for percent organic carbon in accordance with the APHA Standard Methods for the Examination of Water and Wastewater (13th Edition). The sediment particle size distribution was analyzed using a set of standard sieves.

Entrainment - Zooplankton

In order to establish live to dead ratios for zooplankton organisms in the intake and discharge water, samples were collected from the intake bay and approximately 90 seconds later from the discharge at the shoreline. It was assumed that the intake and discharge samples represented the same water mass, differing only in respect to passage through the plant.

The sample volume for obtaining the live to dead ratios was changed over the period of the study. Originally, 200 quarts of water were poured through a #10 mesh Wisconsin plankton net while the net was submerged in a bucket of water to minimize physical stress to the organisms. The 200 quart amount was later reduced to 100 quarts, and finally to 50 quarts to reduce the number of organisms in each sample. The 200 quart volume was used from May 16, 1972 to July 1, 1972, the 100 quart samples from July 1, 1972 to December 31, 1972, and the 50 quart samples for the entire 1973 sampling program.

The zooplankton were incubated for four hours in pint jars at the intake temperature, then stained with 10 drops of one percent neutral red vital stain[3] (final concentration of stain 1:120,000 in each jar) and incubated an additional 1/2 hour. Living organisms became stained, dead organisms did not. After staining, the organisms were removed by sieving and washed in water to remove excess stain. Early in the study, the washed organisms were then preserved in acidic five percent formalin solution and frozen until time became available to sort and count them. Freezing prevented the leaching of stain. In late spring 1973, both motility counts and stained motility counts were done using live material for both sets of observations to determine ratios and verify the results of the staining technique. This was done using zooplankton counting wheels divided into eight small compartments and counting live and dead organisms. The staining greatly facilitated the ease of distinguishing live from dead organisms by enabling investigators to view the movement of the internal organs rather than just waiting for

actual swimming motion. The results were comparable between the two methods utilized. It was concluded that the easiest, and most reliable procedure of establishing the live to dead ratios was to use the stained motility counting method.

Entrainment - Phytoplankton

Samples of water for determining entrainment effects on phytoplankton were collected in the same manner as those for zooplankton.

Relative photosynthetic rates were measured with C^{14}, using modifications of the light and dark bottle procedures described by Strickland and Parsons.(4) Each sample set included two 300 ml BOD light bottles and one 300 ml BOD dark bottle from the intake and the discharge. The dark bottles were wrapped in extra-heavy duty aluminum foil and all sample bottles, both light and dark, were wrapped in double layered hardware store nylon screening. This eliminated direct sunlight inhibition of photosynthesis in the light bottles. The dark bottles were wrapped in the screening so that they received equal treatment. Both sample sets were incubated four hours in a 20-gallon glass aquarium at the intake water temperature after the addition of 2 ml of C^{14} solution of 2 microcuries strength. Natural sunlight was used as the source of illumination.

After incubation, each 300 ml sample was filtered in a darkened area using a HAWP 0.47 µm membrane filter. After filtration, the filters were washed with 50 ml of distilled water to remove any C^{14} adhering to the cells or particulate matter. The filters were placed in 1-dram vials, dissolved in 5 ml of laboratory grade acetone to break down the filter and organic matter, and then prepared for counting on a Packard-Bell liquid scintillation counter.

After counting, the two light sample counts were averaged, corrected for uptake in the dark bottle and adjusted for background count. A percentage reduction of photosynthetic activity was calculated as follows:

$$\text{Percent Reduction} = \left(1 - \frac{\text{Mean of Effluent Rates}}{\text{Mean of Intake Rates}}\right) 100$$

Attached Filamentous Algae

The lake bottom off the Palisades Nuclear Power Plant was surveyed for attached filamentous algae and rooted aquatics on 3 and 4 October 1972, 15 and 16 September and 14 and 15 October, 1973. Two divers began each of five transects from the shoreline and swam out in a direction perpendicular to the shore (direction was kept by compass readings). Two transects were begun onshore but were conducted at a 45° angle to the shoreline. The five transects conducted perpendicular to the shore were run out to a maximum depth of 35 feet, or approximately 1,600 feet offshore. The two 45° angle transects were conducted out to the 25 foot depth, but were approximately 2,400 feet in length. The approximate distances are not actual measured distances, but coincide with the depth levels in this area as measured

during previous surveys for depth contours. Each dive lasted approximately 25 to 40 minutes, during which time the bottom was surveyed for any plant growth.

Michigan Department of Natural Resources - Fish Collections (Gill net, seine & trawl)

The sampling plan consisted mainly of gill netting and seining four times a year -- May, June, August and October. Over the 6-year period, weather and equipment problems forced some changes but the usual practice was to set four graded-mesh gill nets in the vicinity of the power plant in 10-20 feet and 40 feet of water. In 1968, nets also were set at a depth of 60 feet. Gill nets of eight different descriptions were used at one time or another, but three kinds were used consistently throughout the sampling period. Starting in 1971, new nylon gill nets were used that were 250 feet long and consisted of five 50-foot panels of the following mesh sizes: $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3 and 4 inches, stretched mesh. Float and lead lines were so constructed that no floats or leads were attached to them. In June 1971, a complement of the old nets was fished simultaneously with the new ones at the same depths. Net sets were made both perpendicular and parallel to the shoreline and, when present, within and outside the thermal plume. Two overnight sets for each net were scheduled for each visit but there were occasions when weather or equipment problems forced the curtailment of activities. The amount of netting fished in any one visit ranged from 625 to 2,090 feet.

When conditions permitted, shoreline seining was done in addition to the netting, mostly along the beach of Van Buren State Park, which adjoins the Consumers Power Company property on the north side.

The seining area was approximately 3/4 mile north of the point of discharge. One trip was made to the park in December to seine in early winter but ice packs along shore prevented it. Seine hauls also were made on two occasions at Covert Township Park some five miles south of the plant. Whenever possible the seining was done both during the day and at night. A 125-foot bag seine was used between 1968-1972. In 1973, this seine was replaced by a 75-foot bag seine but collections were made with both seines in June for comparative purposes. Mesh size of the bag was 1/4-inch; the rest of the seine contained mesh of 3/4-inch bar measure. Most fish captured at night were preserved for later identification and enumeration in the laboratory.

A small amount of trawling was done in 1969 by personnel of the U.S. Fish and Wildlife Service, at DNR's request, with a 39-foot trawl. Also, in 1972, the DNR staff trawled with a 15-foot trawl.

At each visitation surface water temperatures were taken with a pocket thermometer. In 1972 and 1973 the presence of a plume was detected both with an electrical thermometer (after ascertaining the ambient water temperatures near South Haven) and maximum-minimum thermometers attached to float lines of the gill nets.

All fish caught were measured and counted. Many were weighed and a sample of scales was taken from the middle of the left side of the fish and below the lateral line. Fish were aged from plastic impressions of the scales under a micro-projector.

For the most part, rates of growth were determined from mean lengths at capture, but back calculations were made for some fish caught in June. Body-scale relationships, computed by U.S. Fish and Wildlife Service biologists at the Great Lakes Fisheries Laboratory, for perch taken mostly from nearby Saugatuck were used. The relationships, in millimeters, are:

(1) Length = 30 + 1.58345 (scale length) - for perch under 105 mm.

(2) Length = 14 + 1.72845 (scale length) - for perch over 105 mm.

The length-weight equation was calculated from 503 lengths and weights taken during the surveys. This equation is:

$$\text{Log } W = -2.388 + 3.240 (\text{Log } L)$$

The formula is applicable to both males and females. Separate tabulations were made of mean weights at 0.5-inch intervals for each sex, but the data were combined when no appreciable differences were noted.

Additional Fish Trawling

Trawl collections were made periodically in 1972 and 1973 during the day in the following four areas:

1. Control area located approximately 5 miles south of the plant and out of the influence of the plume.

2. South boundary area located approximately one-half mile south of the discharge.

3. Discharge area directly off the discharge structure.

4. North boundary area located approximately one-half mile north of the discharge.

Trawl collections were made by towing a 25-foot otter trawl along the bottom at two separate water depths, 10 foot and 25 foot, parallel to the shore. A third tow was made at the above four locations by pulling the trawl perpendicular to the shore from the 4 foot to 25 foot depths. The trawl was towed on the bottom of each area and thus was seldom directly affected by the heated water, except during the perpendicular tows at the discharge structure where the plume formed the whole water mass. Trawling was done with a heated discharge both present and absent.

Additional Fish Gill Netting

In 1973, 23 gill net sets were made using a 125 foot variable mesh gill net. These sets were made at the mouth of the discharge and in the immediate vicinity of it, under both heated and nonheated discharge conditions.

Additional Fish Seining

Seine collections were made periodically in 1972 and 1973 during the day and at night to sample for diurnal and nocturnal shoreward movement. Five areas were seined during each collecting trip, except when weather changes forced some to be cancelled.

1. Control area located approximately 5 miles south of the plant and out of the influence of the plume.
2. South boundary area located approximately one-half mile south of the discharge.
3. South of discharge area approximately 600 feet of shoreline going south from the discharge piling.
4. North of discharge area approximately 600 feet of shoreline going north from the discharge piling.
5. North boundary area located approximately one-half mile north of the discharge.

Seine collections were made using a 125 foot bag seine in 1972 until shoreline erosion and high water eliminated much of the beach area and prevented the use of the large seine. A 50-foot bag seine and a 40-foot minnow seine were then used for the 1973 seine collections. The seines were pulled parallel to the shore for a distance of 300 feet and then pulled into shore. Usually two 300-foot sections of shoreline were seined at each area, if weather permitted, for a total sampling of 2,400 to 3,000 linear feet, depending on whether both areas 3 and 4 were seined. Usually only a single discharge area was seined, depending upon the direction of the plume.

Fish Impingement

The plant intake water flows through 3/8-inch mesh traveling screens and all fish collected on the screens were sluiced into a collection basket where they were identified, counted, weighed, and measured on a daily basis. Representative samples were sometimes examined, where individual counts were impractical. The screens were usually run twice per 24-hour period, except during heavy runs of fish when they were run continuously. Collections were made from January 23, 1972 to October 25, 1973. Counts made from January 23 to May 16, 1972 were done by plant personnel, whereas counts made after May 16, 1972 were done by Consumers Power Company biologists.

Fish Eggs and Larvae

The intake water was periodically monitored in 1972 and 1973 for fish eggs and larvae using two methods. The first was by means of a #10 mesh Wisconsin plankton net suspended in the water at various levels from a weighted rope. The second method was to pump water for a set number of hours by means of a 0.25 hp self-priming centrifugal pump, which delivered a calculated 12 gallons per minute.

Thermal Plumes

The method generally employed to measure the plume was to take surface temperature measurements approximately every 50 meters along predetermined transect lines. Directional lights on the plant turbine building roof enabled the boat to stay on line, and distances were measured using a telurometer radar system, with one unit located on the shoreline and the other in the boat. Surface temperatures were generally taken until nearly ambient conditions were reached. Temperature profiles were periodically recorded along each transect to establish the depth of the plume. Both measurements were used to establish the relative size of the plume.

Argonne National Laboratory Thermal Plume Measurements

These plume temperature data were acquired from a moving boat equipped with a submerged boom having thermistor probes attached at 1/2 meter intervals from the surface down to 3 meters. The analog temperature information acquired from the seven thermistors was digitized and recorded on printed paper tape. Lake depth, boat position information, and time were also simultaneously recorded on the same data tape. Boat position information was obtained from a Motorola "Mini-Range" radar system which consists of two shore based "transponders" and a receiver-transmitter unit and range console located on board the boat. Range information from each transponder was sampled and later translated by trilateration into boat position.

The paper tape information was later key punched and computer processed with appropriate calibration information to plot the temperature data as a function of boat position. In general, seven horizontal temperature levels corresponding to the seven thermistor outputs were generated and plotted via Cal-Comp output. Isotherms were drawn by hand because experience has shown the data distributions to be unsuitable for use with available two dimensional computer interpolational schemes. Vertical cross sections of the plumes were obtained by identifying the boat transects of interest on the horizontal sections and then having them Cal-Comp plotted.

Intake Current Measurements

In August 1972 and October 1973 scuba divers descended on the intake and held a current meter in place at the center of each of the four sides of the intake structure. The Argonne team used a Bendix Q-15 meter while Consumers Power Company personnel used a single count 623 electric current meter manufactured by the W & LE Gurley Company. Observations of fish activity were also recorded.

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SECTION A

TEMPERATURE, INTAKE CURRENTS
AND SEDIMENT ANALYSIS

TEMPERATURE

Temperature profiles were measured periodically on the sampling grid during the preoperational study period, but a continuous and representative record of ambient lake temperatures is available from the South Haven water treatment plant intake records (Figures A-1, A-2). Lake temperature data were also taken coincident with all biological surveys. The temperature data taken during the benthic surveys after the plant began operations are given in Tables A-1A through A-7A of Appendix A.

Analysis of the continuous temperature record indicates that ambient summer temperatures in 1972 to 1974 were cooler on the average than the preoperational years, as monthly average temperatures did not rise above 15°C during the latter period.

Rapid changes in ambient temperature were observed on several occasions during the study period. For instance, there was a temperature drop of several degrees in the surface waters during the 1973 August survey, due to mixing caused by rough overnight weather, but the bottom temperatures were not altered.

Upwellings of cold, deep lake water also occur periodically and one such occurrence was recorded by the Michigan Department of Natural Resources during fish netting in June 1968. The temperature dropped from 17.8°C to 8.4°C during sampling.

At the Palisades Plant, cooling water is taken from Lake Michigan through an intake crib located at a depth greater than 20 feet below the lake's surface, 6 feet above the lake bottom, and 3,300 feet from the shoreline (see Figure A-3). The crib is a 57-foot wide, 57-foot long, 12-foot high box with a steel plate for its top and 2-inch vertical bars spaced 10 inches apart around the sides. Water flows horizontally between the vertical bars. The once-through circulating water flow was approximately 400,000 gpm and discharged directly at the shoreline.

Plant intake and discharge temperatures were monitored continuously to determine the range and relative fluctuations in temperature experienced by aquatic life in the intake and discharge areas. The intake and discharge temperatures for 1972 and 1973, the period of once-through cooling operation, are shown on Figure A-4. The benthos and plankton field survey periods are also shown on the exhibit.

The temperature rise through the plant varied from less than 10°F (5.6°C) during the period of 20 percent operation to 28°F (15°C) at 60 percent operation with only one circulating pump operating. The maximum temperature rise with both pumps operating was 17.5°F (9.7°C) during 60 percent operation and 24°F (13°C) during 85 percent operation, which was the maximum plant output during the period of investigation. Maximum discharge temperatures measured in the discharge canal reached 101°F (38.4°C) in July 1973. The decrease in temperature at plant shutdown was sometimes rapid, as can be seen from Figure A-5 for March 19, 1973, ambient temperature being reached in less than about 10 minutes when the intake temperature was 38°F (3.4°C).

There were long periods of time after start-up when the plant was not operating prior to the June 1972 survey, but there was a week and a half of thermal discharge immediately before sampling began (Figure A-4). The difference in temperature of the intake and discharge water was less than 10°C. At the time of sampling, the discharge temperature had dropped to approximately 5°C above surface ambient at the stations nearest to the discharge. The elevated temperature was continuous to the bottom at G/2, H/2 and H-2. Gradual decreases in temperature with depth occurred at the other stations.

Plant operations continued with short breaks in operation before the 1972 October survey, when there was an intake-discharge temperature difference of 10°C. The temperatures at the closest stations were only about 1°C above ambient during the October survey.

The plant was off-line during part of January 1973, the whole of February and then on-line continuously from late March to the May survey. The discharge temperature was 16.5°C above the intake temperature, and the surface temperatures at the sampling station most influenced by the plume, H/4, were 7°C above ambient. There was only about a 1°C temperature difference or less between surface and bottom at all stations, with depths of 45 feet or less.

The plant was off-line during the latter part of May 1973, and operation began again approximately ten days before the June survey. The temperature difference between intake and discharge was 15.5°C and the nearest stations had a surface temperature about 6°C above ambient. The bottom temperatures were generally unaffected by the plume.

The plant was shut down before the August survey and remained off-line for the remainder of the study period.

Periodic thermal plume measurements gave an indication of the area of lake surface, depth, and shoreline that might be affected by temperature changes. A total of 21 plumes were measured by Consumers Power Company survey personnel during the study, and an additional 15 were measured by Argonne National Laboratory personnel. A summary of thermal plume characteristics for all measured plumes is given in Table A-1.

Plume behavior was affected by many factors, with wind and resultant lake conditions being dominant. Based upon wind direction measurements and observed plume behavior, it is apparent that the majority of the plumes traveled in a northerly direction, either northwest out into the lake (as shown in Figure A-6) or north along the shore (such as in Figure A-7). The winds associated with these plumes came predominantly from the south, either south, southeast or southwest. Figure A-8 shows a plume traveling in a southwesterly direction with a 5 mph N-NE wind. Occasionally plumes went in the opposite direction to the wind, but this was probably due to lake currents established by previous prevailing winds.

The summer plumes were deepest at the point of discharge and usually floated to the surface, where they became thinner, until they eventually were indistinguishable from the ambient lake water. Only rarely were plumes measured that would have had a direct influence on the bottom at the sampling grid locations.

The early spring plumes, however, were usually deep for extended areas, reaching bottom over much of the identifiable area of influence. Three sinking plumes were encountered during the period of once-through cooling operation; April 6, 1972, March 8, 1973 and March 23, 1973.

A problem in interpreting thermal plume data arises in the definition of ambient lake temperature conditions. Natural horizontal thermal gradients were apparent on many occasions, with the shoreline ambient being several degrees warmer than the offshore surface. The input of solar energy during the length of time required to chart a plume also caused occasional additional surface warming, which made plotting the edge and shoreward areas of the plume extremely difficult.

The areas and respective lengths of thermal plumes that could be defined in the neighborhood of the $3^{\circ}F$ ($1.67^{\circ}C$) level above ambient, their average depths and range of depths are tabulated in Table A-1. The average size of the plumes mapped according to the approximate $3^{\circ}F$ above ambient definition, was 231 acres, with a range of 17 to 870 acres in surface area. The majority of the plumes were greater than 200 acres in surface area. The main axis of the plume averaged 1.3 miles in length, ranging from .1 to 4.4 miles. The majority of the plumes were greater than 1 mile in length.

Another aspect of the effect of the plume concerned melting of the pack ice. Figure A-9 shows a typical photograph of this phenomenon, indicating that the discharge caused a pool or melted area, but did not cause significant melting of ice at the shoreline.

INTAKE CURRENTS

As discussed above, the intake crib is submerged 3,300 feet offshore. The average velocity at the face of the intake was designed to be about 0.5 ft/second, but direct current measurements were required to determine the maximum velocity to aid in interpretation of fish movement observations.

On August 15, 1972 and October 14, 1973, scuba divers descended in the vicinity of the intake to measure current velocities and observe fish movement. The former survey was conducted by a survey team from the Argonne National Laboratory and CP Co personnel. The latter survey was conducted by a CP Co survey team. Water velocities at the center of each face of the intake structure ranged from .69 to .95 ft/second. The current velocity results of both surveys are included in Appendix A, Table A-8A.

SEDIMENT ANALYSIS

Sediment samples were taken for particle size and percent organic carbon analysis on two occasions (October 1971 and 1973) at all the stations sampled in the 1971 preoperational surveys. The results of these analyses are included in Tables A-9A and A-10A of Appendix A.

Comparison of the percent organic carbon indicated that there was no increase in organic material from the 1971 levels except at Stations CS-2 near the St Joseph River, CN1 near the Black River and C-5 a deep station five miles distant from the plant site. The only stations in the vicinity of the plant where slight increases had occurred were F/2, D/2 and H-1. Most of the stations showed decreases, eg, at G/2 the 1971 level was 2.65 percent and in 1973, 0.22 percent. Generally at stations in less than 60 feet of water, organic carbon levels were lower and more consistent. The mean results for stations less than 60 feet deep were less than 0.5 percent in 1973, compared to greater than 1.0 percent in 1971.

Particle size analysis indicated a range in size from greater than 4.76 mm (pebble) to less than 0.074 mm (very fine sand) in the Wentworth classification of particle size(1). The predominant particle size was between 0.074 mm and 0.297 mm (very fine to medium sand).

The particle sizing of the sediments indicated a trend towards a higher proportion of material passing through the finer meshed sieves. The 1973 sediments had higher proportions of finer material than the 1971 sediments.

All of the 21 to 40 foot stations in 1973 contained finer materials (less than 0.149 mm) than in 1971. The finest sizes were of similar proportions in both years except at C-5 and F-5 where 22 percent and 28 percent of the substrate, respectively, was less than 0.074 mm diameter in 1973, compared to 0.4 percent and 0.2 percent, respectively, in 1971. These stations also contained the highest percent organic carbon in 1973.

Visual observations of bottom materials by scuba diving are described in Section B.

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1. Cummins, K. W., and Lauff, G. H., 1969, "The Influence of Substrate Particle Size on the Macrodistribution of Stream Macrobenthos," Hydrobiologia 34: 145-181.

TABLE A-1
Summary of Thermal Plume Measurements
at the Palisades Plant

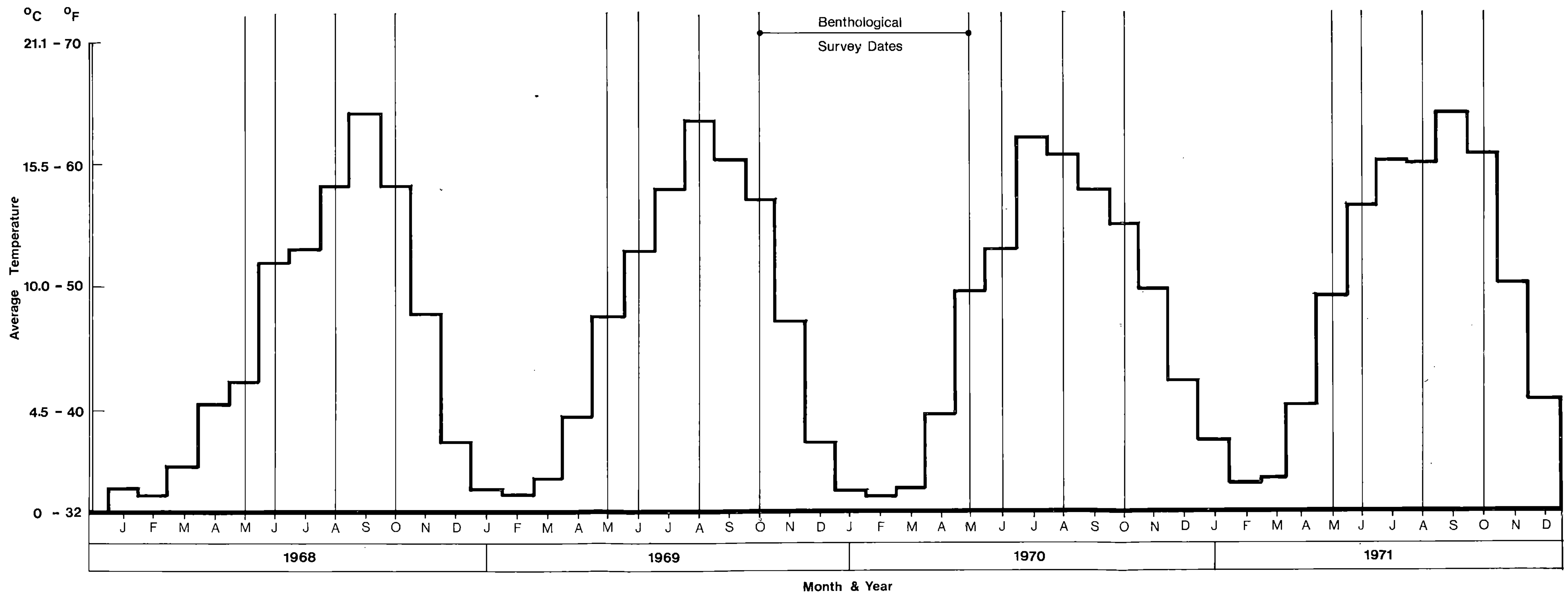
Date	Approximate Plant Load MWe	Temperature of Isotherm Determined °F	Temperature of Isotherm Determined °C	Isotherm Increase Above Ambient °F	Isotherm Increase Above Ambient °C	Approximate Area Acres	Plume Length - Miles Main Axis	Plume Length - Miles Influence	Average Depth of Plume Feet	Range of Depth of Plume Feet	Direction of Plume Travel (1)
4/06/72	385	37.5	3	0.8-1.4	.44-.78	-	0.4	0.4	-	-	SO
6/06/72	415	69	20.6	3-4	1.7-2.2	200	1.7	1.7	2	2-4	SO
6/13/72*	420	64.4	18	2.7-6.3	1.5-3.5	213	1.2	1.2	1½	½-5	NS
6/13/72*	420	66.2	19	3.6-5.8	2.0-3.2	312	2.3	2.3	1	½-5	NS
6/19/72*	415	62.6	17	2.5-3.8	1.4-2.1	96	1.5	1.5	1	½-5	NS
6/20/72*	412	62.6	17	4.1-4.5	2.3-2.5	55	0.5	0.5	1	½-5	NS-NO
6/20/72*	412	62.6	17	2.5-3.8	1.4-2.1	88	0.6	0.6	1½	½-6	NS-NO
6/20/72*	412	66.2	19	5.4-5.8	3.0-3.2	69	0.6	0.6	1	½-2½	NO
6/20/72*	412	66.2	19	3.2-4.1	1.8-2.3	78	0.8	0.8	1	1-1½	NS-NO
7/10/72	427	71	21.6	4-5	2.2-2.8	320	1.7	1.7	2	2-10	NS
7/11/72	428	70	21.1	4	2.2	870	4.4	4.4	2	1-5	NS
7/17/72*	185-415	75.2	24	2.7-3.2	1.5-1.8	107	0.8	0.8	2½	1-3	NS
7/18/72*	415	75.2	24	2.7-3.6	1.5-2.0	341	1.6	1.6	3	1-5	O
7/19/72*	420	77	25	0.9-2.7	0.5-1.5	238	0.7	0.7	4	1½-5	O-NS
7/21/72	426	80	26.6	3-4	1.7-2.2	198	0.8	1.8	2	½-4	NS
7/27/72	428	56	13.4	4	2.2	57	0.4	0.4	3	½-5	O
8/07/72*	432	59	15	6.7	3.7	71	0.6	0.6	8	6½-10	SS
8/08/72*	433	60.8	16	6.3	3.5	161	0.7	0.7	8	6½-10	NS
8/10/72	435	67	18.9	1-3	.6-1.7	170	2.5	2.5	6	5-9	NS
8/25/72	418	77	19.4	3-4	1.7-2.2	72	0.4	0.4	3	2-8	O
10/10/72*	434	59	15	3.1-3.8	1.7-2.1	85	0.4	0.4	2½	1½-4	O
10/11/72*	435	62.6	17	6.3	3.5	145	0.4	0.4	8	6½-10	NS
10/13/72*	433	57.2	14	2.3-2.5	1.3-1.4	69	0.5	0.5	5	3-6½	NO
3/08/73	581	44	6.7	4-6	2.2-3.3	650	1.5	1.9	10	4-20	NO-NS
3/23/73	583	43	6.1	3-6	1.7-3.3	340	1.1	2.2	10	1-11	O-SS
5/18/73	702	56	13.4	2-4	1.1-2.2	215	1.2	1.2	3½	3-4	NO
6/05/73	728	68	20.0	3-5	1.7-2.8	530	1.5	1.5	2	1-3	NS
6/06/73	726	72	22.2	2-7	1.1-3.9	260	1.0	1.0	3	1-6	NS
6/12/73	719	75	23.9	1-5	.6-2.8	560	2.0	2.0	2	1-3	NS
6/20/73	717	76	24.5	4-5	2.2-2.8	100	1.0	1.0	3	1-5	NO
6/25/73	715	70	21.1	4	2.2	250	1.2	1.2	2	1-2½	NS
7/09/73	710	73	22.8	3-6	1.7-3.3	276	1.5	1.5	2½	2-3	NO
7/20/73	713	75	23.9	3	1.7	477	2.5	2.5	2	1-3½	NS
7/24/73	716	75	23.9	4	2.2	17	0.1	0.1	2	1-3	O
7/31/73	714	77	25.0	3-4	1.7-2.2	356	1.6	1.6	1½	1-2	NS
8/02/73	715	70	21.1	3	1.7	56	2.2	2.2	-	-	SS

*Survey Conducted by Argonne National Laboratories

(1) NS - North along shore
NO - North offshore
O - Offshore
SO - South Offshore
SS - South along shore

Figure A-1

Temperature Record for Preoperational Survey Period.

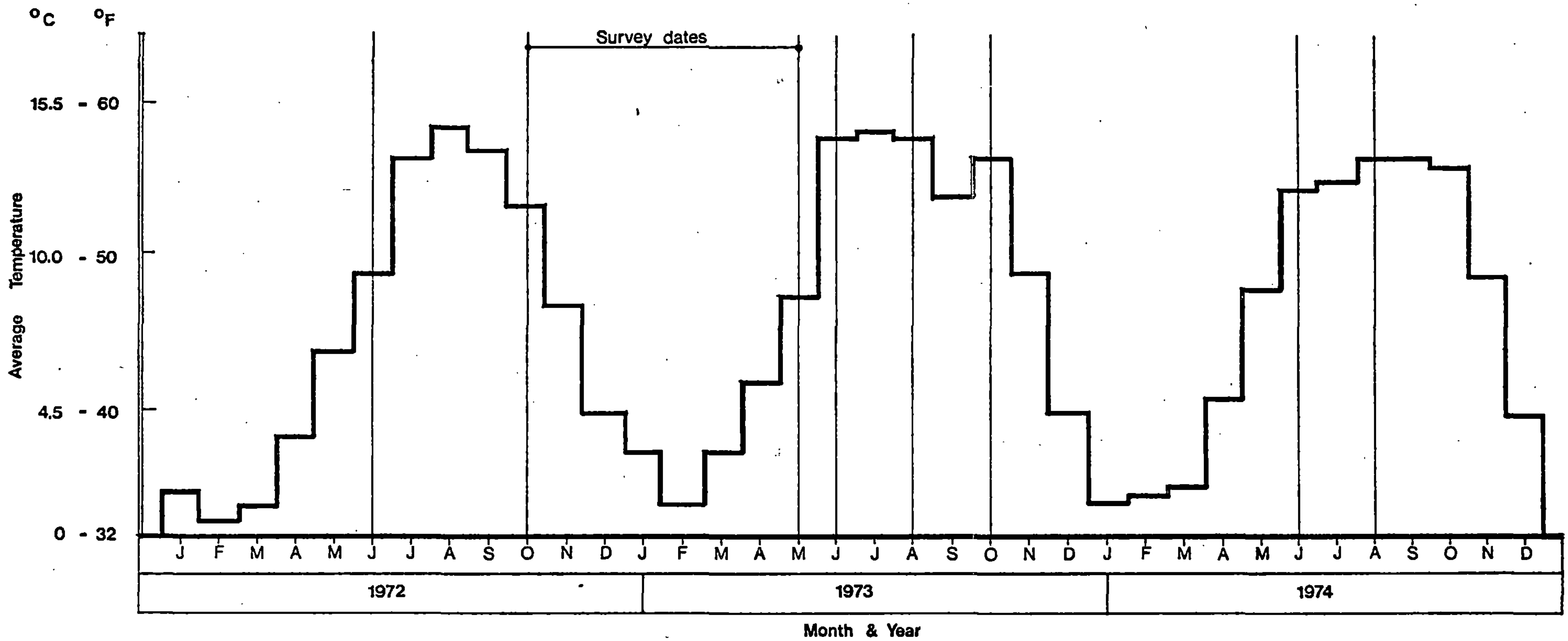


Note
- South Haven Water Treatment Plant Intake, 35 ft. deep 1.1 miles offshore

Figure A-2

Ambient Temperature Record for Postoperational Survey Period

Note :
South Haven Water Treatment
Plant Intake 35 ft deep 1.1 miles



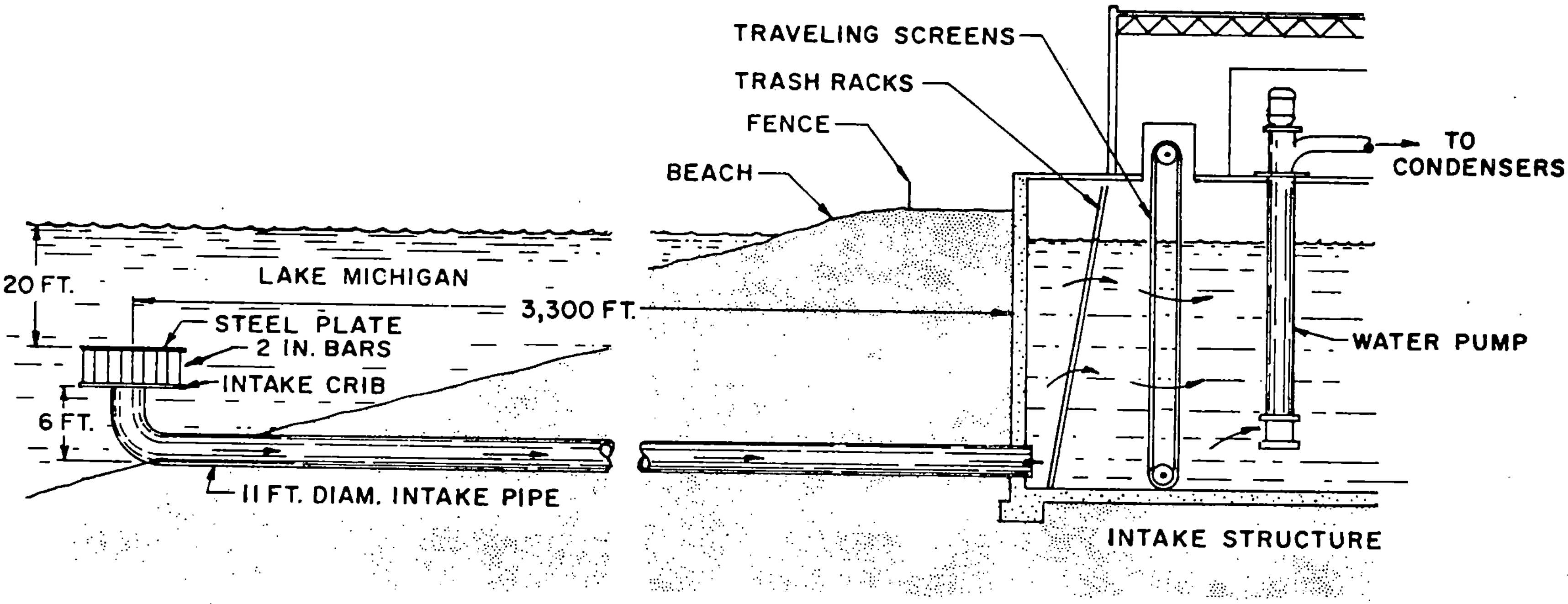


Figure A-3 Schematic of Water Intake System
Palisades Plant

Figure A-4

Intake and Discharge Water Temperatures

Jan 1972 – Oct 1973

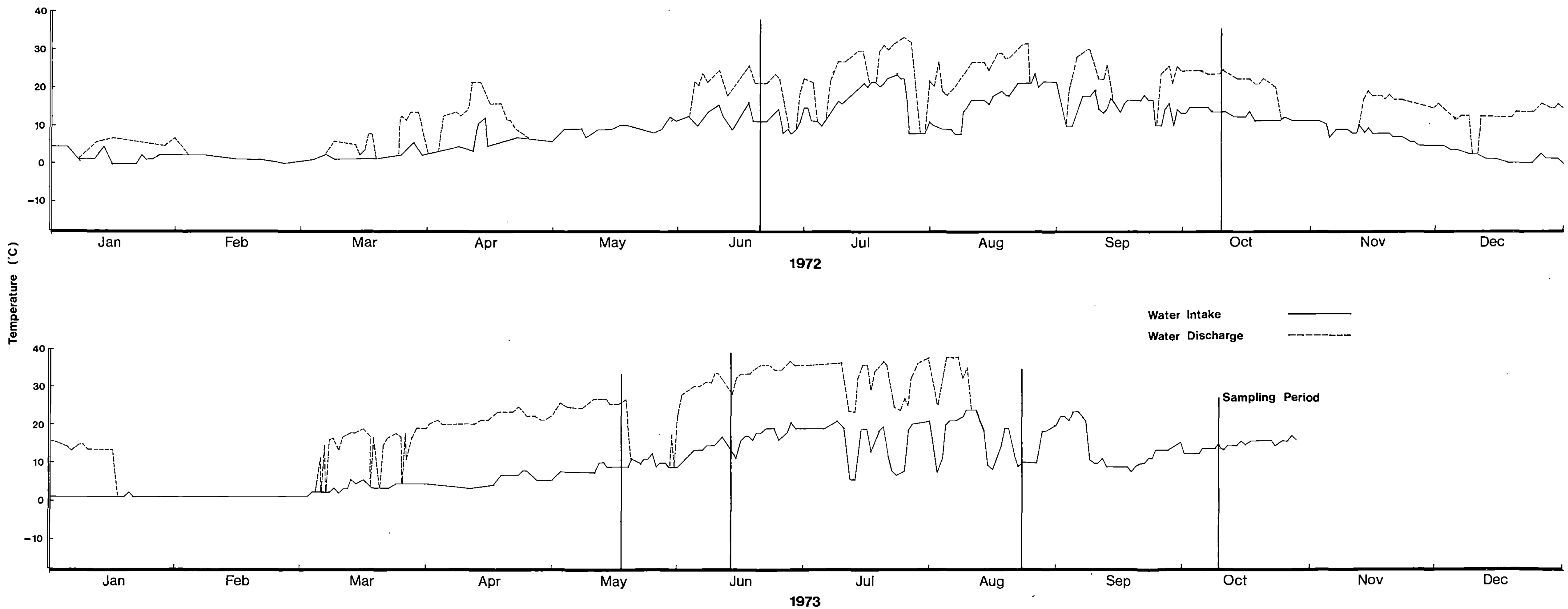
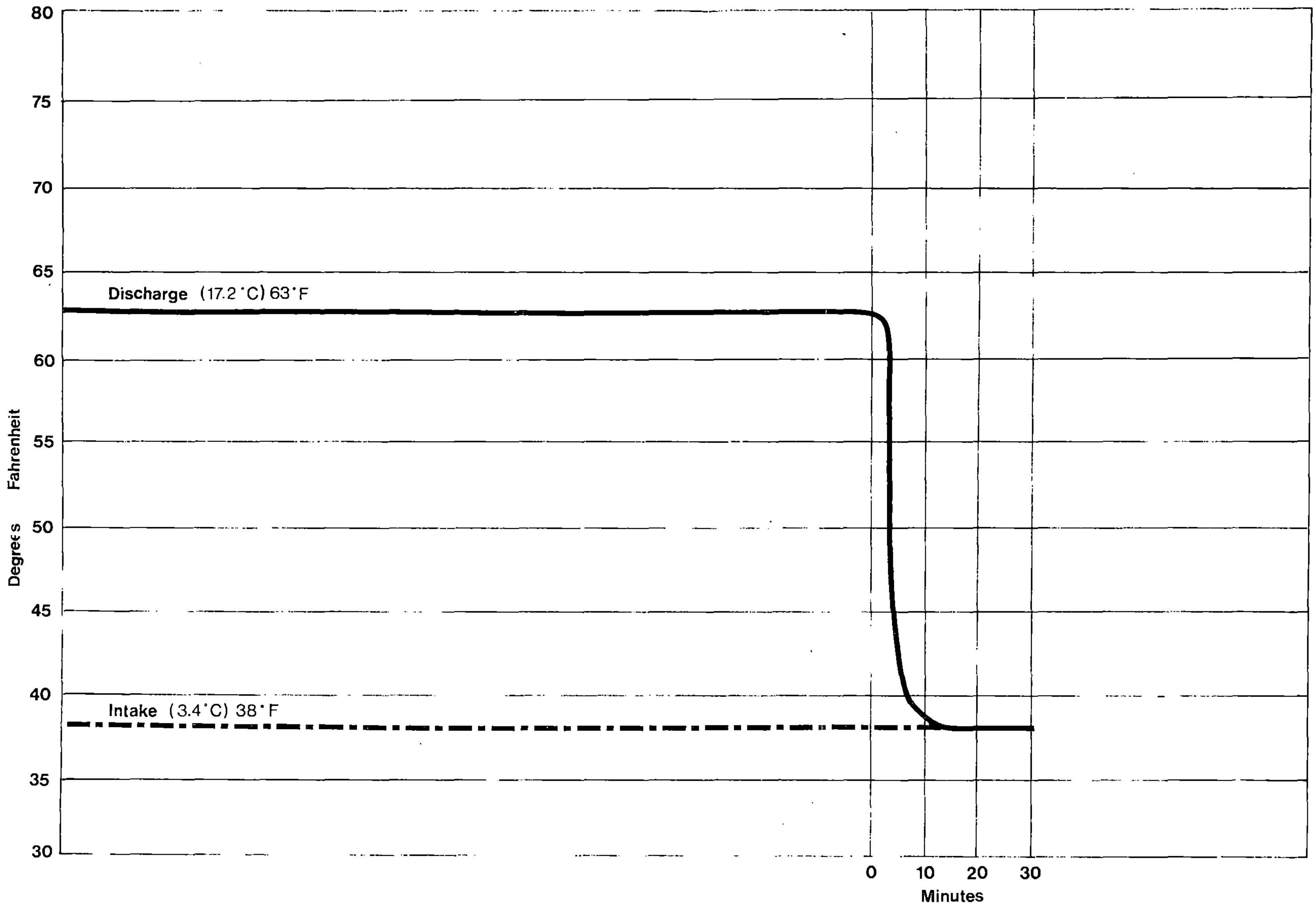


Figure A-5

Palisades Plant - Rate of Temperature Decrease during One Plant Shutdown - 19 March 1973.



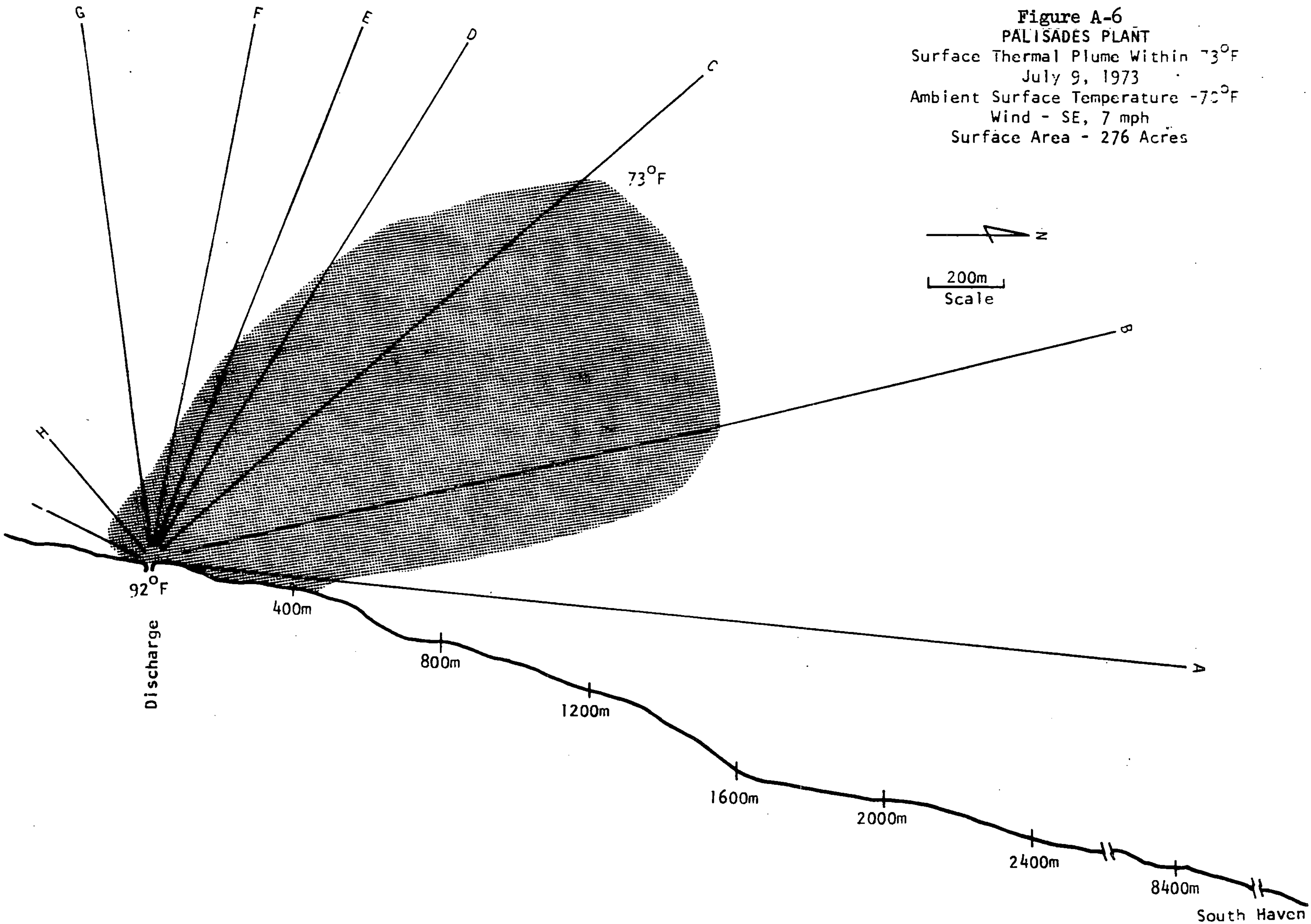


Figure A-6
PALISADES PLANT
Surface Thermal Plume Within 73°F
July 9, 1973
Ambient Surface Temperature -70°F
Wind - SE, 7 mph
Surface Area - 276 Acres

P[illegible]SADES PLANT
Surface Thermal Plume Within 70°F
July 11, 1972
Ambient Surface Temp = 66°F
Wind S-SW, 7.5 mph

Scale ~ 600m

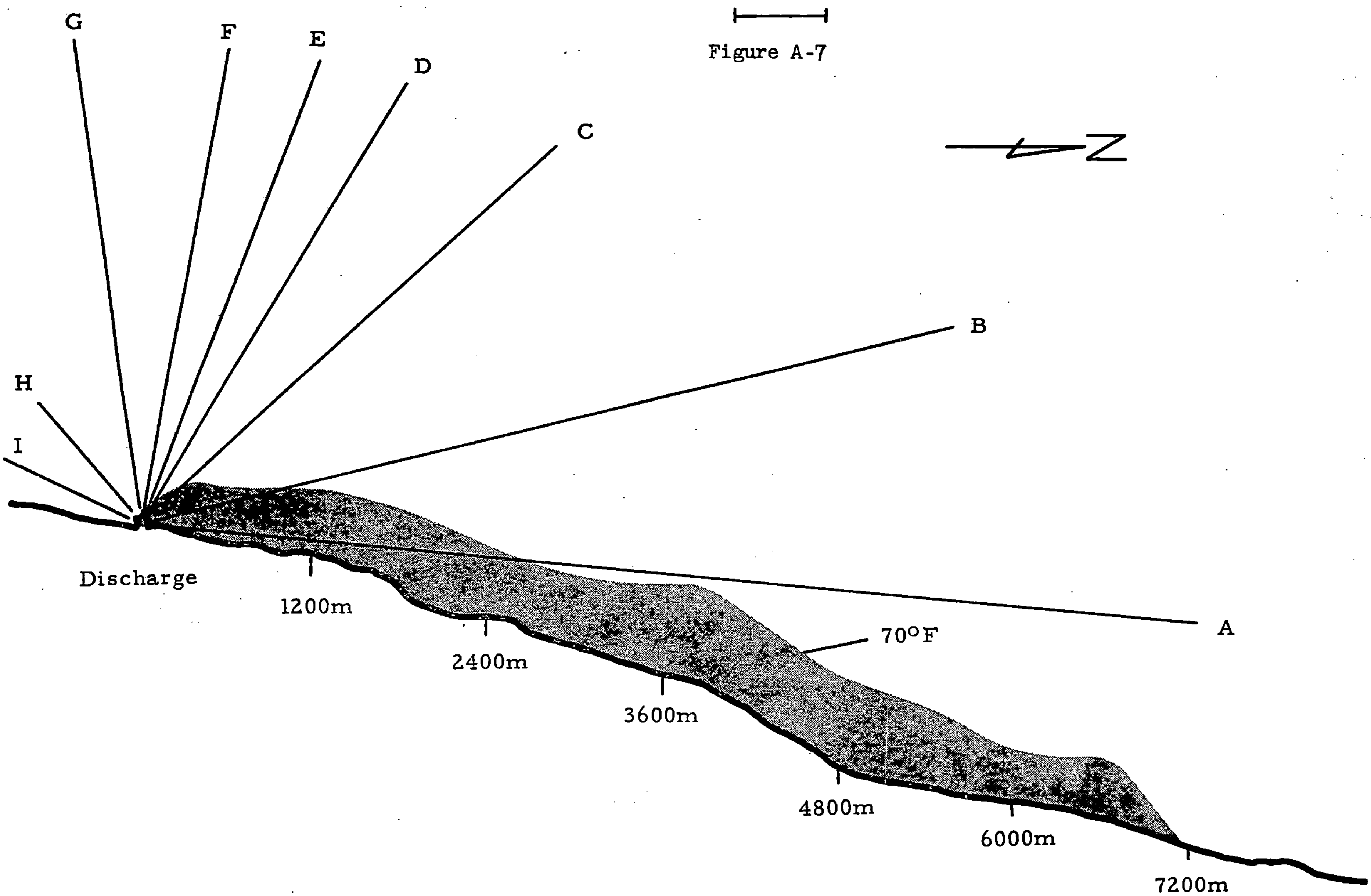
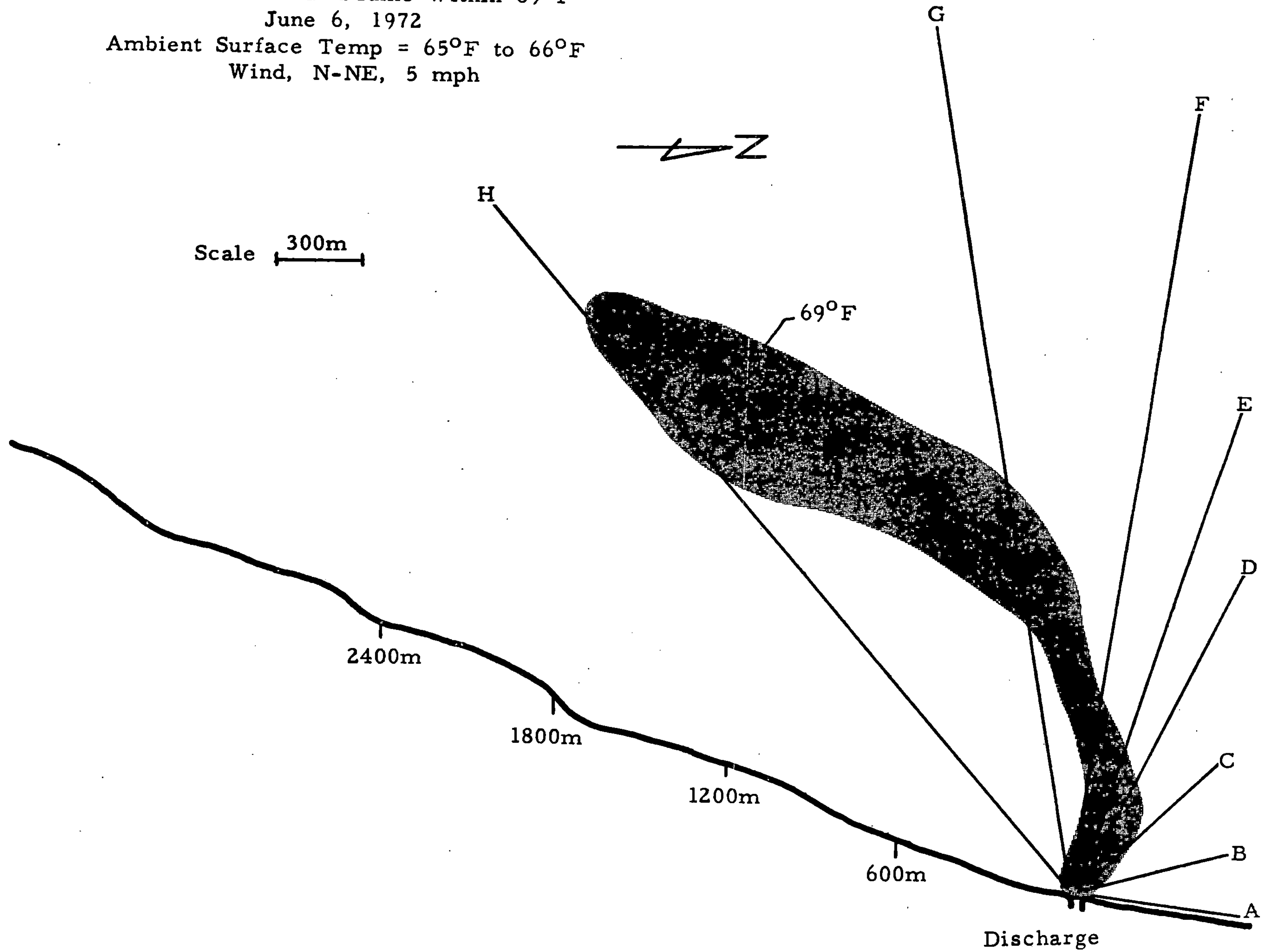


Figure A-7

Figure A-8

PALISADES PLANT
Surface Thermal Plume Within 69°F
June 6, 1972
Ambient Surface Temp = 65°F to 66°F
Wind, N-NE, 5 mph



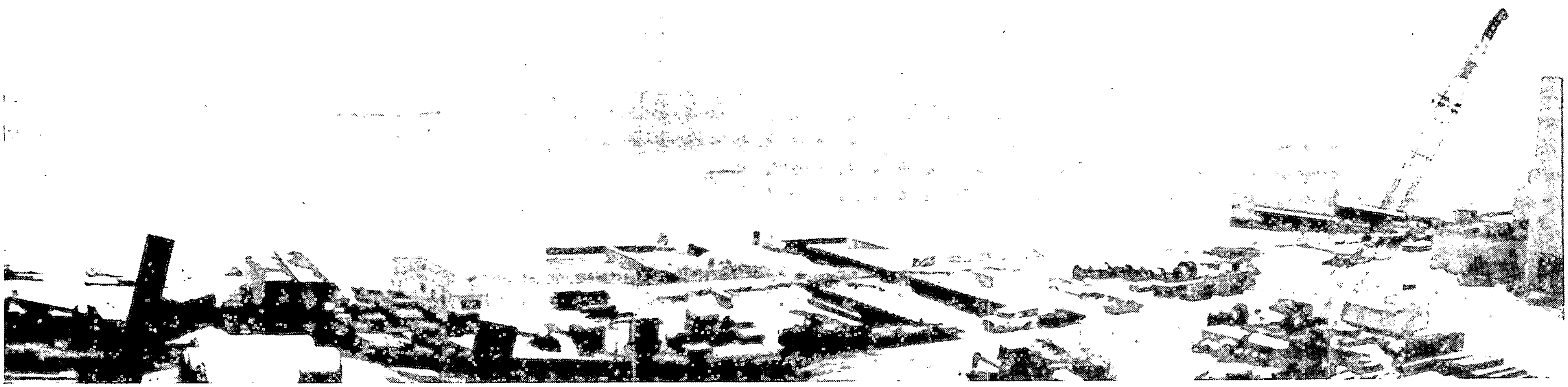


Figure A-9

Palisades Plant

Influence of Circulating Water on
Ice Formation Along the Shoreline
1/15/73

Intake Temp = 33°F Discharge Temp = 56°F

SECTION B

PLANKTON, ATTACHED FILAMENTOUS ALGAE AND ROOTED AQUATICS AND PSAMMOLITTORAL ORGANISMS

PLANKTON

Packed Cell Volumes

The average packed cell volumes for plankton sampled at the grid stations offshore of the Palisades Plant and at the control stations from 1968 through 1974 are shown in Figure B-1. Standard deviations were calculated for the samples from the Palisades stations and for the samples from the control stations, when their mean did not fall within the deviation of the Palisades samples.

Substantial variations in plankton standing crop between 1968 and 1974 were indicated by the packed cell volumes. In August 1968 and May 1971, before the generating station became operational, significant differences in packed cell volumes had already occurred between the Palisades stations and the control stations. However, trends in the rise and fall of standing crops of plankton, as measured by packed cell volume, were parallel at the Palisades and control stations. Variation among the Palisades stations increased greatly as the average packed cell volume increased.

The plant was operational during the June and October 1972 and May and June 1973 sampling periods. In June 1972 and May and June 1973 packed cell volumes were relatively low but volumes at the control stations were similarly low. In October 1972 average packed cell volume was relatively high but this seems to be part of a trend which has continued to 1973 and is apparent at both the Palisades and control stations.

Bivariate control charts were also constructed to aid in comparison of packed cell volumes between selected inner and outer stations at various depth intervals. While 42 percent of the inner-outer pair points analyzed during the period of operation were outside the control chart limits, none of the results indicated a change in the quantity of plankton at the inner stations. These charts are included in Appendix B.

Since plankton were sampled between 5 and 15 feet, the temperature recorded for each sampling station at 10 feet during the operational periods was examined. The means and standard deviations of these temperatures for Palisades and control stations are given below.

	Temperature (°C)	
Date	Palisades	Control
19 June 1972	14.0 ± 3.14	11.8 ± 1.65
9 October 1972	13.2 ± 0.26	13.4
15 May 1973	10.2 ± 0.50	9.9 ± 0.75
14 June 1973	18.7 ± 0.64	19.3 ± 1.15

Variations in temperatures in the lake great enough to significantly influence plankton occurred only during the June 1972 sampling period. The temperatures recorded at the Inner Palisades stations on this date are shown on Figure B-2 and indicate that a thermal plume from the plant extended for about two miles south from the plant. The packed cell volumes determined at all the stations in June 1972 and their relationship to the temperature at 10 feet are shown in Figure B-3a. Packed cell volumes determined at five stations where the temperature is greater than 16°C were very low. A comparison of the volumes for these five stations, and one other close by for which no temperature data are available, which were in the center of the plume, is made with the volumes for the other stations.

Packed Cell Volumes (ml/80 l)

Plume Stations	Other Stations
Temperature $> 16^{o}C$	Temperature $< 16^{o}C$
$\bar{x} = 0.04 \pm 0.02$	$\bar{x} = 0.25 \pm 0.15$
$n = 6$	$n = 29$

The average packed cell volume for the six stations within the plume was 16 percent of that for stations outside the plume and probably reflects in large measure the variability in plankton populations between the intake water and shoreline waters on this date.

Phytoplankton Composition

Phytoplankton were identified and enumerated at one station in the plume, H-1, during the June 1972 sampling period. This station had the lowest number of organisms of ten stations monitored on that date.

The correlation between packed cell volume and phytoplankton densities for June 1972 is shown in Figure B-3b. Since this correlation is fairly good it can be assumed that low packed cell volumes in the plume indicated low densities of phytoplankton.

Figure B-4 shows the variation in the composition of the net phytoplankton by group from 1972 to 1974 for June and October. In this graph, the data from all the sampling stations are pooled and averaged. The composition of the net phytoplankton by groups has remained relatively stable since 1972, the bulk of the organisms being diatoms (Bacillariophyceae). The blue-green algae (Cyanophyta) have contributed only a small amount of the total numbers. In June 1972, about one-quarter of the phytoplankters were Dinobryon. The graph indicates a rise in total net phytoplankton population in October 1973, and June 1974, when the plant was not in operation, which agrees with the increase in biomass as indicated by the measurements of packed cell volumes.

Tabellaria, Asterionella, Fragilaria, Cyclotella, Melosira, and Synedra, were all dominant genera at one time or another. Other commonly occurring genera were Navicula, Rhizosolenia, Scenedesmus, Pediastrum, Dinobryon, and Oscillatoria.

Numerous studies have been made of the phytoplankton of Lake Michigan, but on the whole, as various methods of sampling and analysis were used, the data presented above are not directly comparable with the results of these studies. Stoermer and Yang[1] give an excellent review of the plankton diatom assemblages and their relationship with specific environments in Lake Michigan. Ayers and Seibel[2] discuss the relative densities of total phytoplankton populations as presented in several reports on Lake Michigan. They show that reported average densities at inshore stations range from 800 to 3,000 cells/ml and at offshore stations from 400 to 1,400 cells/ml. Phytoplankton densities as reported in the Palisades study (Inner stations) ranged from 10 to 1,000 times lower than this. Since phytoplankton biomass at the Palisades site, as determined by visual counts since 1972, correlates well with packed cell volumes, and since the packed cell volumes subsequent to the start-up of the plant are similar to those reported prior to start-up, this apparent paucity of phytoplankton cannot be attributed to operation of the plant. The difference in values is probably due to different experimental approaches. Only net phytoplankton were monitored at the Palisades study and colonial or filamentous plankters were enumerated as one (1) organism.

Relative Photosynthetic Activity of Phytoplankton Samples Before and After Entrainment

Fifty-two sets of radiocarbon experiments were performed on plankton samples collected before and after entrainment through the Palisades Plant on 25 separate occasions from 24 May 1972 to 27 August 1973. Figure B-5 shows the percent increase or decrease in photosynthetic activity for all samples. Ten samples showed increased activity, two showed no change, while the majority of the samples (41) showed decreases in activity. When no heat was present (17 sets of samples) change in productivity varied from 68.1 percent loss to a 109 percent gain in the discharge samples, with an average loss of 35.6 percent (based on 12 samples) and an average gain of 35.4 percent (based on four samples), with no change in one sample. With the introduction of heat (35 sets of samples), the change in productivity varied from 89.3 percent loss to a 76 percent gain in the discharge samples, with an average loss of 47.9 percent (based on 28 samples) and an average gain of 36.2 percent (based on six samples) with no change in one sample. If the samples are averaged collectively for the entire study period, but divided up into effects of a heated discharge and a nonheated discharge, the average loss for heated is 32.7 percent and the average loss for nonheated is 17.9 percent, indicating (if the results are valid, considering the patchiness of Lake Michigan plankton populations) that mechanical stress caused approximately one-half the decrease in primary productivity.

The results are similar to those of Hamilton et al[3] and Morgan and Stross[4] who also found reductions and increases in primary productivity in comparable work. The 32.7 percent average loss is similar to decreases noted at the Waukegan Station[5]. The extreme variability in photosynthetic response to the stresses of entrainment and condenser passage indicate that phytoplankton patchiness may be a major problem in obtaining accurate data on photosynthetic activity.

Zooplankton Composition

During the entrainment studies, the most abundant and consistently appearing zooplankton groups were the cyclopoid and calanoid copepods and the Bosmina cladocerans. The copepods appeared in every sample, but Bosmina appeared primarily in the summer months and in large numbers at that time. The dominant forms were Bosmina longirostris, Diaptomus, Limnocalanus, Asplanchna, and Daphnia retrocurva.

Field samples for zooplankton were also taken coincidentally with the phytoplankton survey. Unfortunately a direct comparison of the field and entrainment data is not possible because the field studies were not coincident with the mortality studies. Also, during the field studies, plankton were collected at depths ranging from 15 to 5 feet and filtered through a #25 plankton net. Plankton from the intake were entrained from a depth below 20 feet and all plankton samples were filtered through a #10 net. In addition, the mortality studies concentrated on the crustacean component of the zooplankton, while the analyses from the field studies gave a better description of the rotifers. The most notable variations between the densities observed in the two studies occurred in the fall of 1973 with regard to Bosmina and the rotifers. Both organisms occurred at much greater densities in the field samples than in the intake samples. While these data suggest an avoidance of the intake by Bosmina and the rotifers, it is quite likely that the difference is actually caused by a variation in density of these organisms between the surface and deeper water.

Zooplankton Mortality Resulting From Entrainment

Figures B-6 through B-11 show the live to dead ratios (percent mortality) for calanoid and cyclopoid copepods, nauplius larvae, Bosmina and Daphnia cladocerans, and rotifers for intake samples and both heated and nonheated discharge samples taken from 16 May 1972 to 25 October 1973. A total of 119 separate samples was counted, 83 with a heated discharge and 36 with an unheated discharge.

Due to sampling variability, it is difficult to accurately ascertain mortality rates of zooplankton organisms. In many instances the discharge samples showed lower ratios of dead organisms than did the intake samples taken 90 seconds earlier. The figures depict each type of sampling situation singly, while calculated average percent differences and ranges are presented in Table B-1. Based upon all the samples collected, an average mortality was calculated for the intake samples, the nonheated discharge samples (attempting to establish mechanical damage), and heated discharge samples. As evidenced by the graphs, the average percent mortality varied considerably with each temperature increment, and was probably influenced by many variables that cannot be taken into account. The average percent mortality, however, for both heated and nonheated discharge samples was usually higher than the intake rates for all groups analyzed. There were several discharge temperatures associated with a

single intake temperature. This occurred because the plant was at different levels of capacity (ie, 30, 60 and 100 percent). It is important to note that once the discharge temperature reached 90° to 100°F (32.2° to 37.8°C), the average percent mortality rates went up to above 90 percent in some groups. This indicates the upper lethal temperature level of the zooplankton was reached and exceeded in these samples. The majority of the samples, however, showed low percent differences between the intake and discharge samples. The Daphnia and rotifer averages are based on fewer samples than the others and should be regarded accordingly.

Because they occurred only rarely in the field samples, the larger zooplankters were not identified. Bosmina was always present in the samples. Keratella cochlearis, Polyarthra sp., and Kellicottia sp. were commonly occurring rotifers. Synchaeta sp. occurred at high densities during October 1973.

The fluctuations in density of the individual groups from year to year were found to be similar. An increase in zooplankton density in the fall of 1973 and the spring of 1974 contributed to the high packed cell volumes measured at these times. The zooplankton were at a much greater density in June 1974 than in June of the previous two years.

ATTACHED FILAMENTOUS ALGAE AND ROOTED AQUATICS

The growth of periphyton and rooted aquatics was not expected to be a problem at the Palisades Plant as there is very little natural substrate on which such organisms can grow.

Artificial substrate samplers were used on six occasions during the preoperational period in the area of the outfall and plant boundaries with varying degrees of success. The growth which occurred was quite low and ranged from 0.1 to 5.33 $\mu g/cm^2$/day in 1970 to 1971. The growth in 1968 was estimated by chlorophyll-a and -b analysis and in subsequent years by dry weight estimates.

Relatively large amounts of filamentous algae were entangled in the seine nets during June 1971, and in the gill nets during August 1971; the only time that this happened. On both occasions, it was not apparent that the material originated in the vicinity of the plant.

During surveys of the lake bottom (Figure B-12) carried out by divers on 3 and 4 October 1972, 15 and 16 September 1973, and 14 and 15 October 1973, no attached filamentous algae or rooted aquatics were observed on the substrate. The area is predominantly sand and small gravel which is unstable during most of the year, leaving little possibility for plants to attach or take root. The typical transect showed the near shore area to be a sandbar which moved constantly as wave, wind and current action changed. Considerable amounts of organic detritus were observed in the shallow areas and out to the 25 foot level. Beyond this level the sand was washed clean. The active area was characterized by wave ripple marks varying in height from 1 to 3 inches and varying in distances apart from 1 to 4 feet, depending on depth. There was an extensive gravel bar, about 15 to 20 feet wide, at the 20 to 25 foot level, that ran the entire length of the survey area, parallel to shore.

The immediate discharge area (approximately 20 feet from the discharge) was the only area which showed any observable change. Due to the velocity of the discharge water, the bottom was washed clean of sand and consisted of large gravel and rocks. Many of the rocks showed evidence of algal growth. The discharge structure itself was covered with Cladophora at and below the waterline as were many of the large rocks on the shore and many of the seawalls in the area, both within and outside the area of thermal influence. A phenomenon observed during both summers was the die-off of Cladophora on the discharge structure after discharge temperatures exceeded 80°F (26.7°C).

The presence or absence of rooted macrophytes and attached filamentous algae along the shoreline was also noted during the four psammolittoral surveys in June and October of 1972 and 1973. Filamentous algae only occurred on the infrequent dead tree trunks or the iron pilings used in erosion control along some sections of the beach. Only small amounts of detached, washed-up algal strands were seen in the way of growth on the natural shoreline.

PSAMMOLITTORAL ORGANISMS

Psammon, microscopic organisms inhabiting the interstitial spaces of sand along the shoreline, were sampled four times during 1972 and 1973; in June and October. The average numbers of organisms at each sampling location are given in Table B-2.

The majority of the organisms in the sand around Lake Michigan were found to be diatoms, which comprised approximately 69% of the total count. The other groups of algae were present in much lower densities. Of the remainder that could be identified, protozoans and rotifers were the most common, with segmented worms and nematodes occurring occasionally. Sporocysts of plant or animal origin were also found in quite large numbers.

Total counts indicated that the cores taken from the sand above the waterline usually contained the highest numbers of organisms, though in June 1973 the psammon was as numerous in the cores taken at the waterline. Average numbers of psammon per core were higher in June 1972 than in June 1973. Sand temperatures were lower in June 1972 than in June 1973, but the differences were not very great. The sand above the waterline is always subjected to large diurnal temperature fluctuations and wave conditions would affect waterline temperatures. The numbers of organisms in the cores from the rough October 1972 period were lower than in October 1973; however, the lower density may have been due to the difficult sampling conditions. The sand temperatures were, however, much higher in October 1973 when calm sunny conditions were present.

In 1973, when weather conditions permitted the two surveys to be completed, higher numbers of organisms occurred in October than in June except in the cores from the North Boundary and South Control. More dense communities were present at these two locations in the waterline cores. Comparison of organism density at the various stations in relation to the distance from the plant did not reveal any patterns, and variability near the plant was comparable to variability at all stations. The largest numbers of organisms occurred in the waterline cores at South Control in October 1973. An average

of 3,627,444 organisms per 10 ml sand was estimated. Other waterline densities ranged from 13,606 to 507,333 per 10 ml sand. The South Control samples were not analyzed in detail but a brief study indicated that the majority of the cells were *Melosira* sp. and *Tabellaria* sp., typical of Lake Michigan plankton. The packed cell volume of the plankton sample from the shallow South Control station was high compared to the sample from the deep South Control CS1. *Melosira* sp. and *Tabellaria* sp. were dominant in the plankton and the high counts in the psammolittoral cores were probably caused by plankton washing up onto the beach.

Detailed analysis indicated that the psammon were composed of a fraction which was probably planktonic in origin (eg, *Tabellaria* sp., *Fragilaria* sp.) and a fraction which was epipelic (eg, *Cyanomonas* sp., Cryptochrysidacea; Pennales, Bacillariophyceae, primarily *Navicula* sp.). Blue-greens were represented in some cores by relatively small numbers of organisms, Chroococcales, *Microcystis* sp. and *Agmenellum* sp. being the most common.

Cyanomonas sp. (Cryptochrysidaceae), an organism with two flagellae of unequal length and stated by Ward & Whipple[6] as being an organism of uncertain position, was present in quite large numbers in some of the cores.

Protozoans were represented by Rhizopoda and Actinopoda, the former being the more common of the two. Rotifera were present, but not in large numbers.

The eggs which were recorded as present, were microcrustacean. No fish eggs were found.

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Table B-1: Average mortality for groups of zooplankton from intake, heated and non-heated discharges at Palisades nuclear plant - 16 May 1972 to 25 October 1974

	COPEPODA						CLADOCERA				ROTIFERA	
	Calanoid		Cyclopoid		Nauplius		Bosmina		Daphnia		Rotifers	
	Avg. (%)	Range (%)	Avg. (%)	Range (%)	Avg. (%)	Range (%)	Avg. (%)	Range (%)	Avg. (%)	Range (%)	Avg. (%)	Range (%)
Intake	16.0	1-91	21.3	1-60	20.9	0-79	20.6	0-83	26.7	0-100	8.1	0-35
Heated Discharge	30.9	3-93	28.7	4-83	33.2	0-80	26.7	0-73	33.5	0- 91	20.3	3-70
Non-heated Discharge	21.5	8-46	27.0	12-66	18.5	5-43	25.2	8-67	25.3	0- 67	14.7	8-20
Percent Difference												
Intake and Heated Discharge	14.9		7.4		12.3		6.1		6.8		12.2	
Intake and Non-heated Discharge	5.5		5.7		-2.4*		4.6		-1.4*		6.6	

*Intake average percent mortality higher than non-heated discharge average percent mortality.

TABLE B-2

AVERAGE NUMBER OF PSAMMOLITTORAL ORGANISMS PER 10 ml SAND
JUNE AND OCTOBER, 1972 AND 1973

STATION:	A-2				A-5			
YEAR:	1972		1973		1972		1973	
MONTH:	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER
Avg.No.of Organisms								
Sand	299,952	Rough	83,333	160,000	67,375	Rough	39,333	85,500
Water line	330,402		15,333	40,667	24,211		12,500	73,333
In water	265,767		118,667	161,333	71,543		48,000	95,000
STATION:	NORTH CONTROL				NORTH BOUNDARY			
YEAR:	1972		1973		1972		1973	
MONTH:	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER
Avg.No.of Organisms								
Sand	28,182	46,000	39,667	140,000	871,876	78,333	177,000	86,333
Water line	67,899	47,467	38,600	150,000	72,640	68,333	19,000	81,000
In water	22,787	8,933	466,667	50,000	78,617	20,333	82,667	77,000

TABLE B-2 (continued)

STATION:	A/2				A-1			
YEAR:	1972		1973		1972		1973	
MONTH:	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER
Avg.No.of Organisms								
Sand	63,372		115,667	400,000	113,577	39,000	90,333	146,706
Water line	39,221	Rough	20,600	99,500	160,131	8,367	27,333	55,333
In water	113,699		85,667	81,000	136,812	13,800	66,667	50,000
STATION:	I/2				I-1			
YEAR:	1972		1973		1972		1973	
MONTH:	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER
Avg.No.of Organisms								
Sand	77,118		193,333	236,667	153,146		67,000	226,667
Water line	181,624	Rough	8,900	32,000	119,374	Rough	34,000	13,666
In water	97,376		62,966	83,000	234,450		41,333	163,500

TABLE B-2 (continued)

STATION:	I-2				I-5			
YEAR:	1972		1973		1972		1973	
MONTH:	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER
Avg.No.of Organisms								
Sand	294,819	Rough	69,667	160,333	89,321	Rough	73,000	74,000
Water line	140,455		17,333	42,666	49,787		25,667	507,333
In water	60,181		41,666	83,666	58,371		90,667	161,000
STATION:	SOUTH CONTROL				SOUTH BOUNDARY			
YEAR:	1972		1973		1972		1973	
MONTH:	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER	JUNE	OCTOBER
Avg.No.of Organisms								
Sand	181,464	Rough	326,667	82,333	-	43,000	-	228,666
Water line	103,875		59,667	3,627,444	-	42,000	-	116,000
In water	89,697		203,333	109,667	-	15,400	-	39,667

- Not sampled

Figure B-1

Fluctuations in Packed Cell Volume of Plankton, 1968-1974 Near Palisades, Michigan.

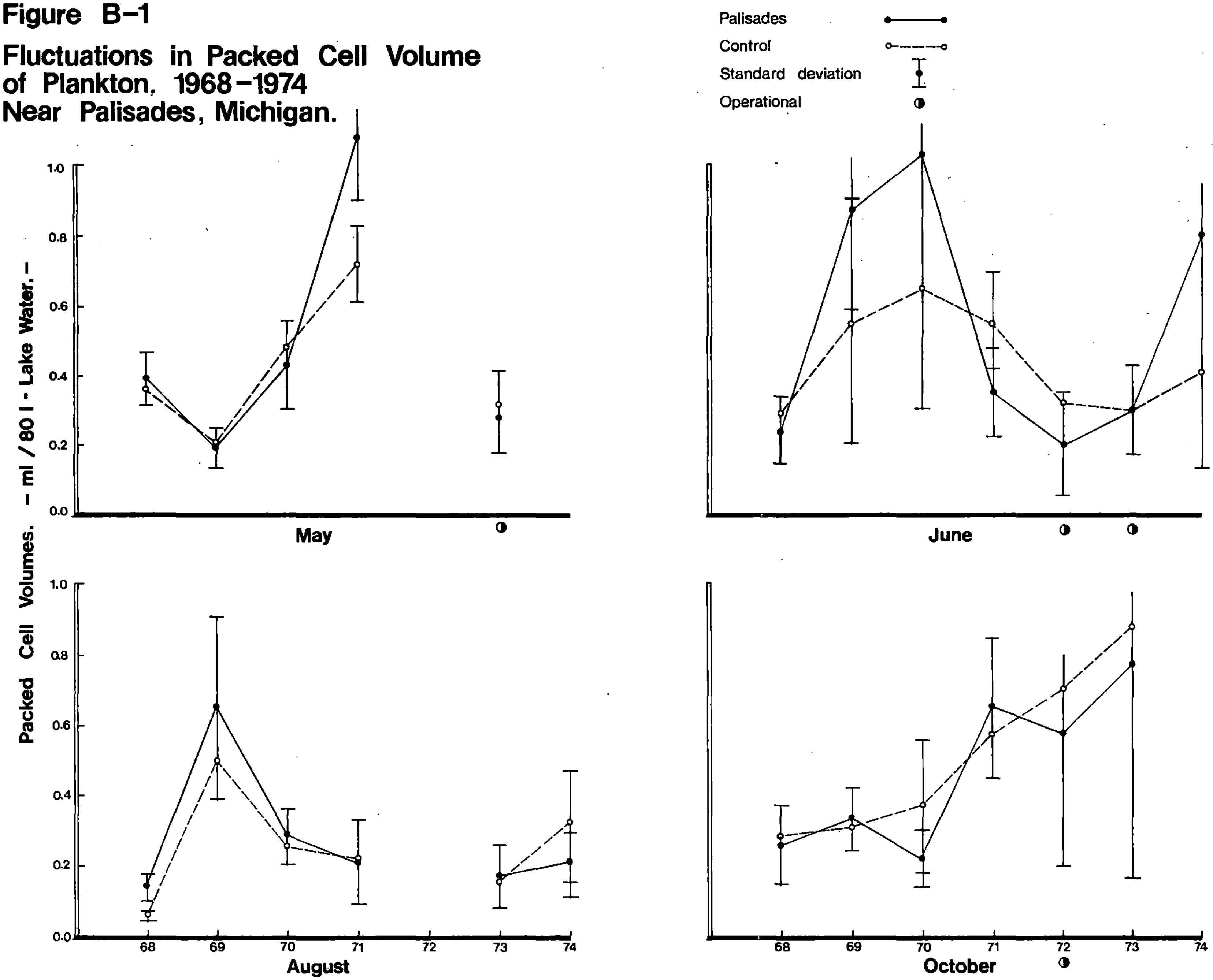


Figure B-2

Water Temperature (°C) at 3m(10 ft) Depth
Lake Michigan near Palisades.
19 June 1972

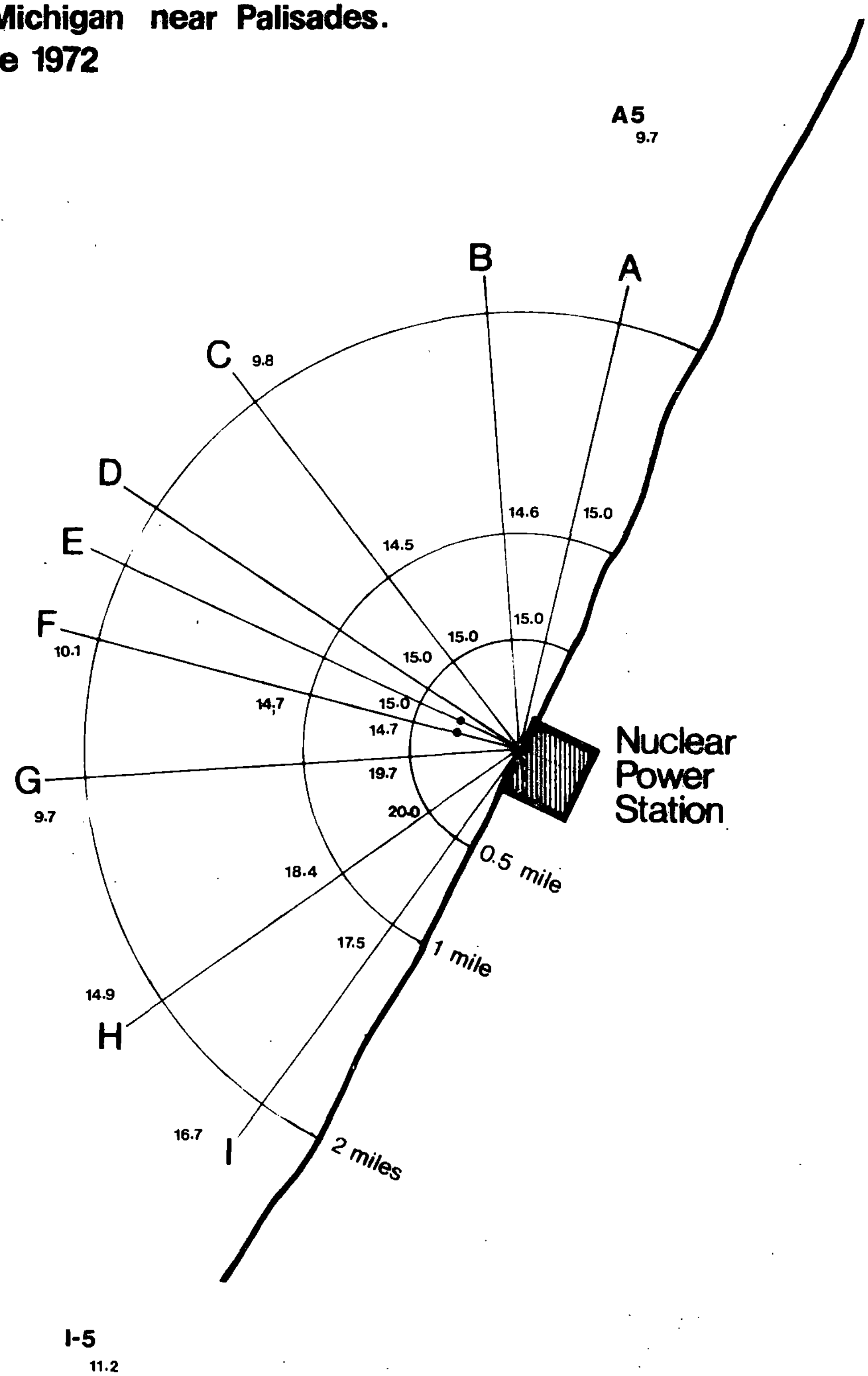


Figure B-3a

Packed Cell Volume of Plankton Related to Lake Temperature at 3m(10ft). June 1972.

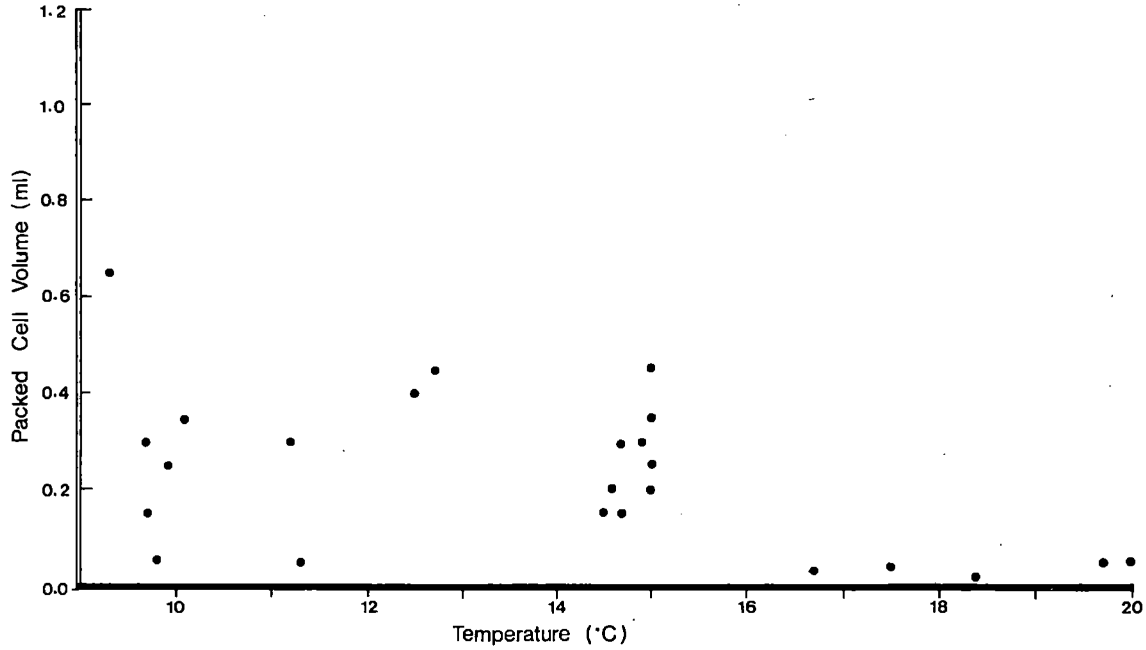


Figure B-3b

A Comparison of Packed Cell Volumes and Phytoplankton Counts for June 1972.

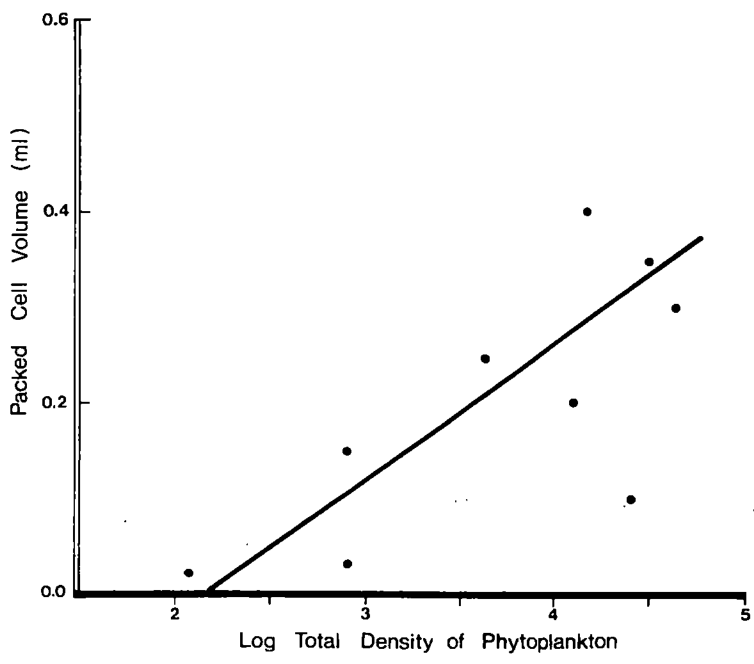
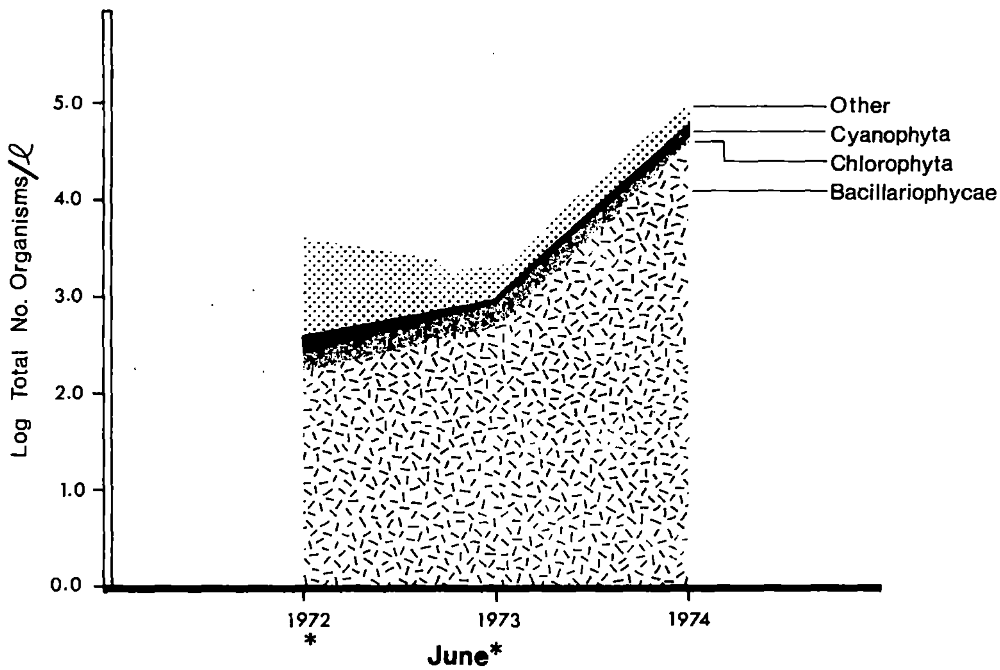
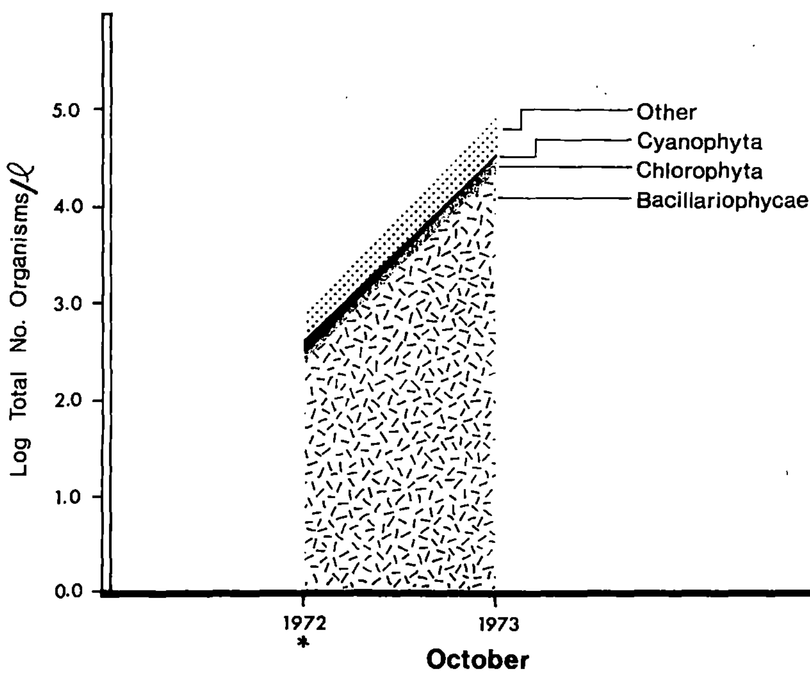


Figure B-4

Composition of Net Phytoplankton Sampled at 10-14 Stations Near Palisades, Michigan.





*Plant In Operation

Figure B-5

Loss or Gain of Photosynthetic Activity for C^{14} Tests for Primary Productivity of Algae Passed Through the Condensers.

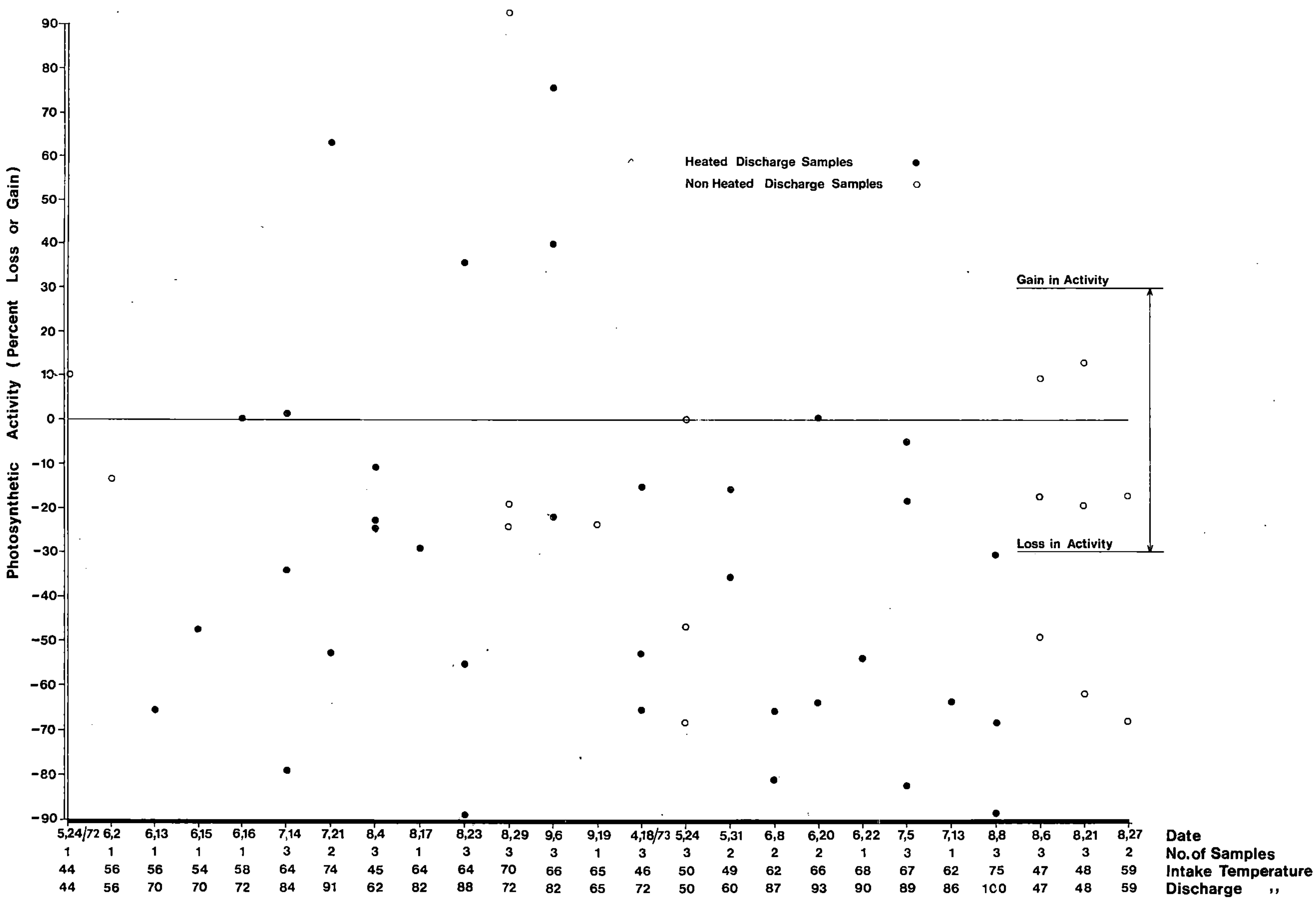
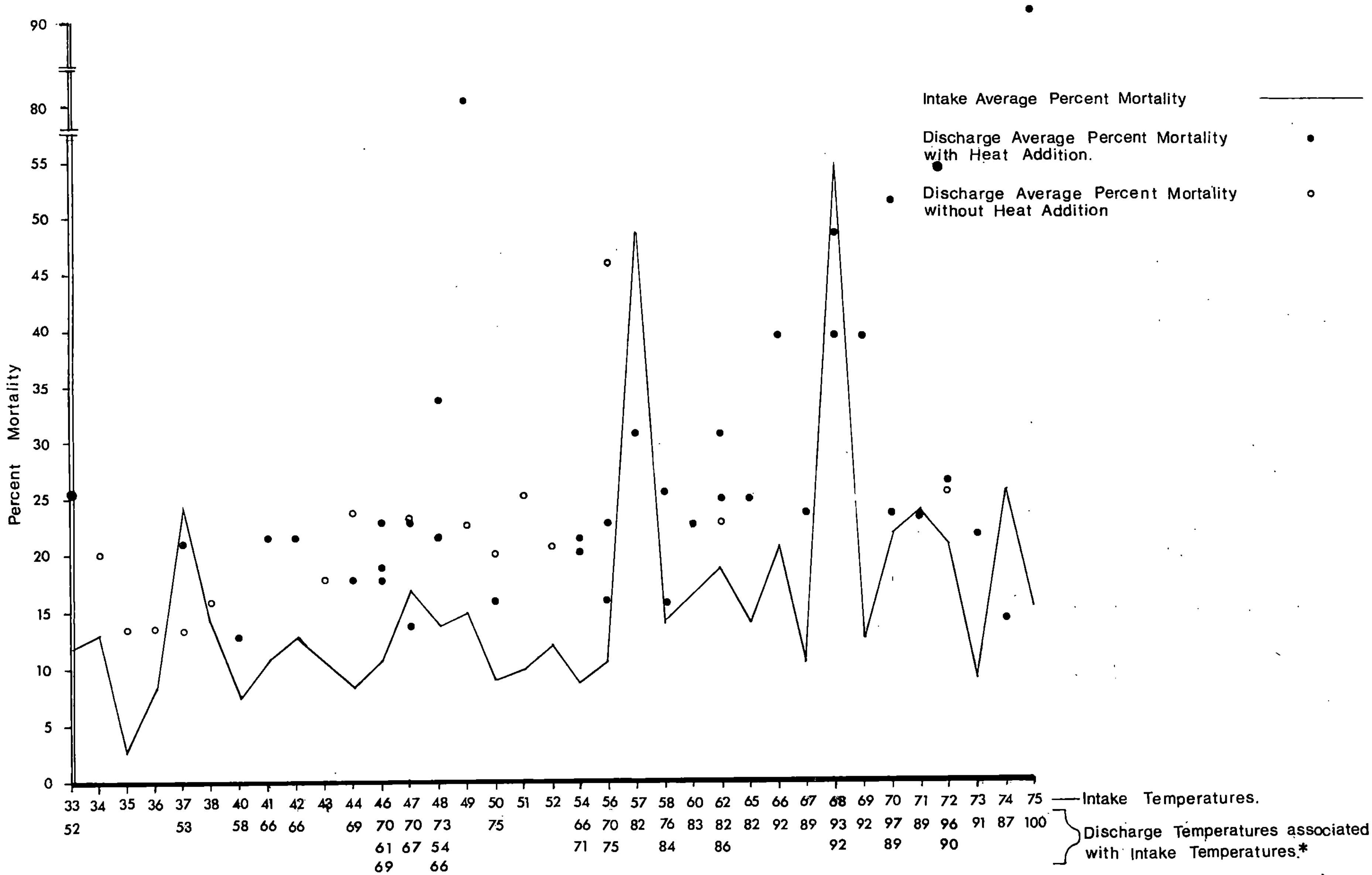


Figure B-6

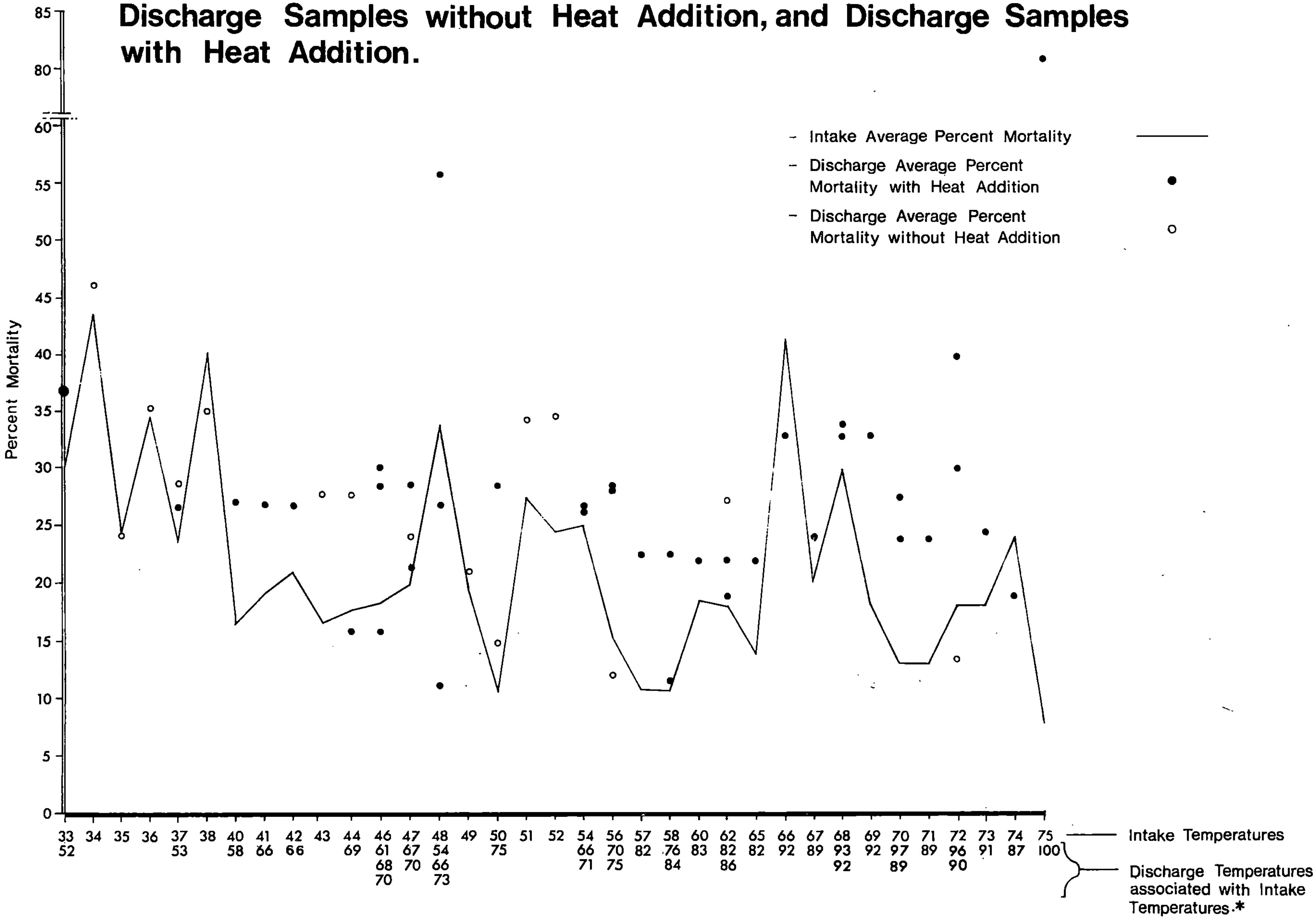
Average Percent Mortality for Calanoid Copepods for Intake Samples, Discharge Samples without Heat Addition, and Discharge Samples with Heat Addition.



*Discharge Temperatures Associated With The Highest Percent Mortalities Are Listed First, And So On In Decreasing Order

Figure B-7

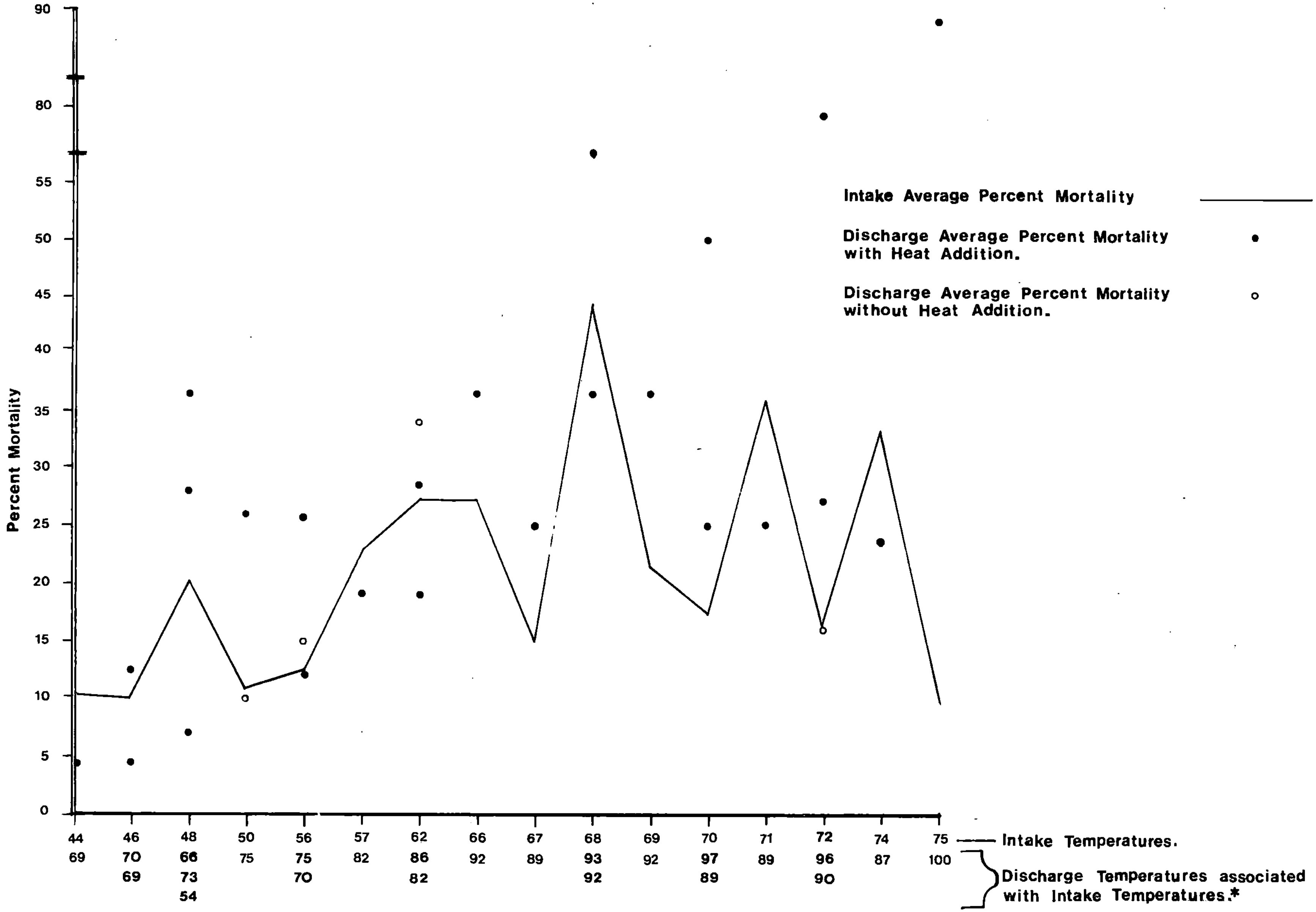
Average Percent Mortality for Cyclopoid Copepods for Intake Samples, Discharge Samples without Heat Addition, and Discharge Samples with Heat Addition.



*Discharge Temperatures Associated With The Highest Percent Mortalities Are Listed first, And So On In Decreasing Order

Figure B-8

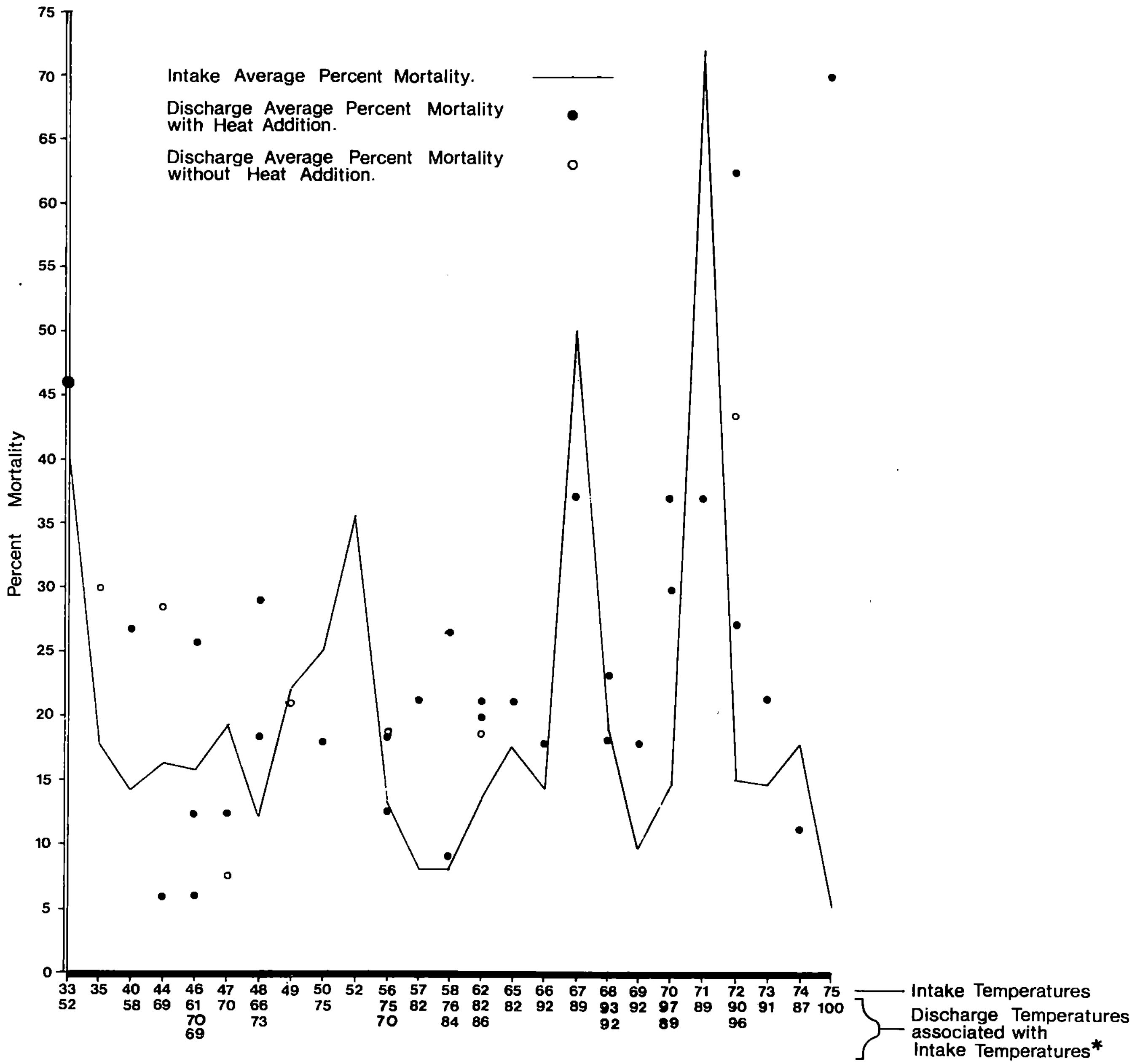
Average Percent Mortality for Nauplius Larvae for Intake Samples, Discharge Samples without Heat Addition, and Discharge Samples with Heat Addition.



*Discharge Temperatures Associated With The Highest Percent Mortalities Are Listed First, And So On In Decreasing Order

Figure B-9

Average Percent Mortality for Bosmina Cladocerans for Intake Samples, Discharge Samples without Heat Addition, and Discharge Samples with Heat Additions.



*Discharge Temperatures Associated With The Highest Percent Mortalities Are Listed First, And So On In Decreasing Order

Figure B-10

Average Percent Mortality for Daphnia Cladocerans for Intake Samples, Discharge Samples without Heat Addition, and Discharge Samples with Heat Addition.

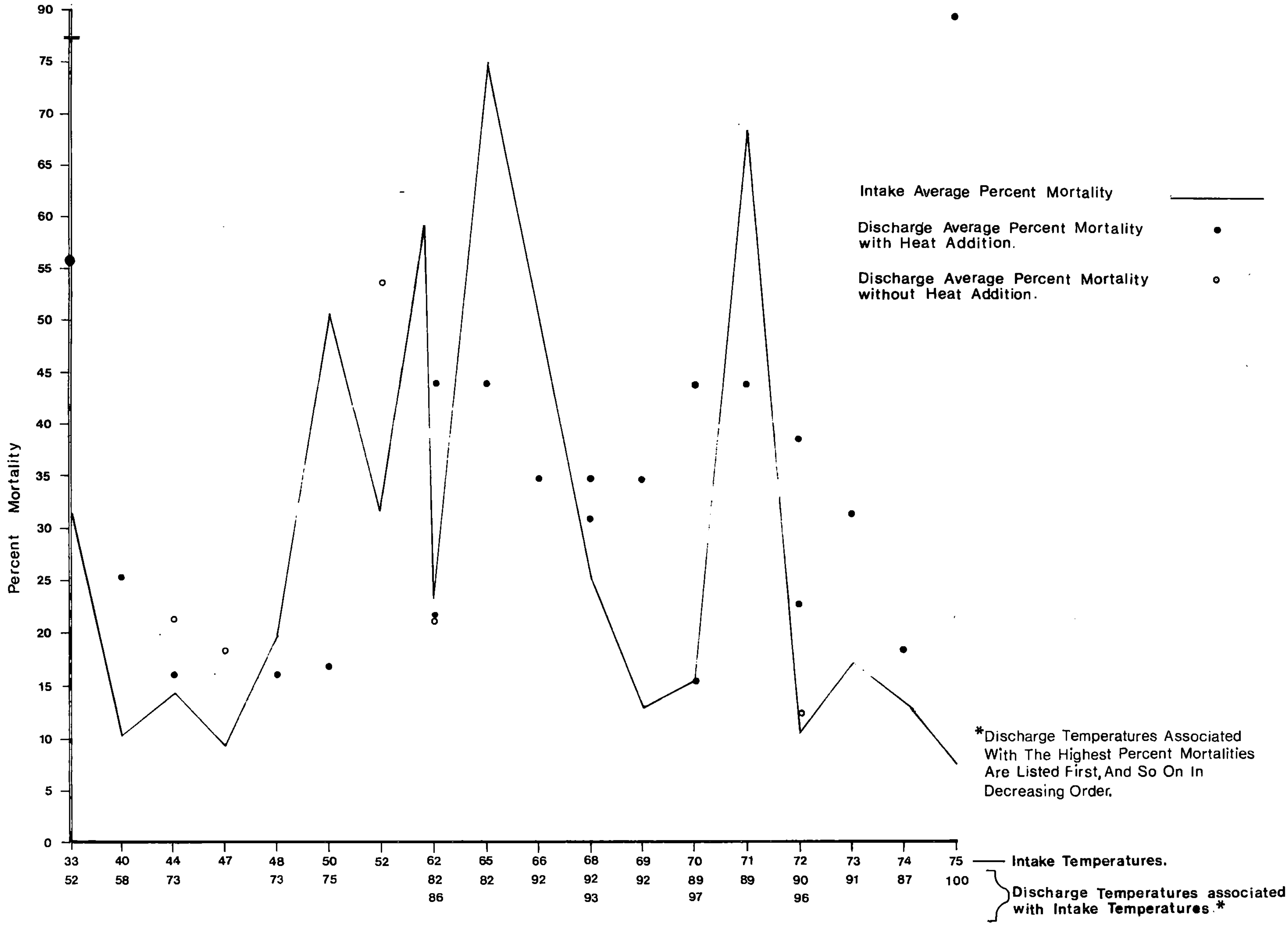
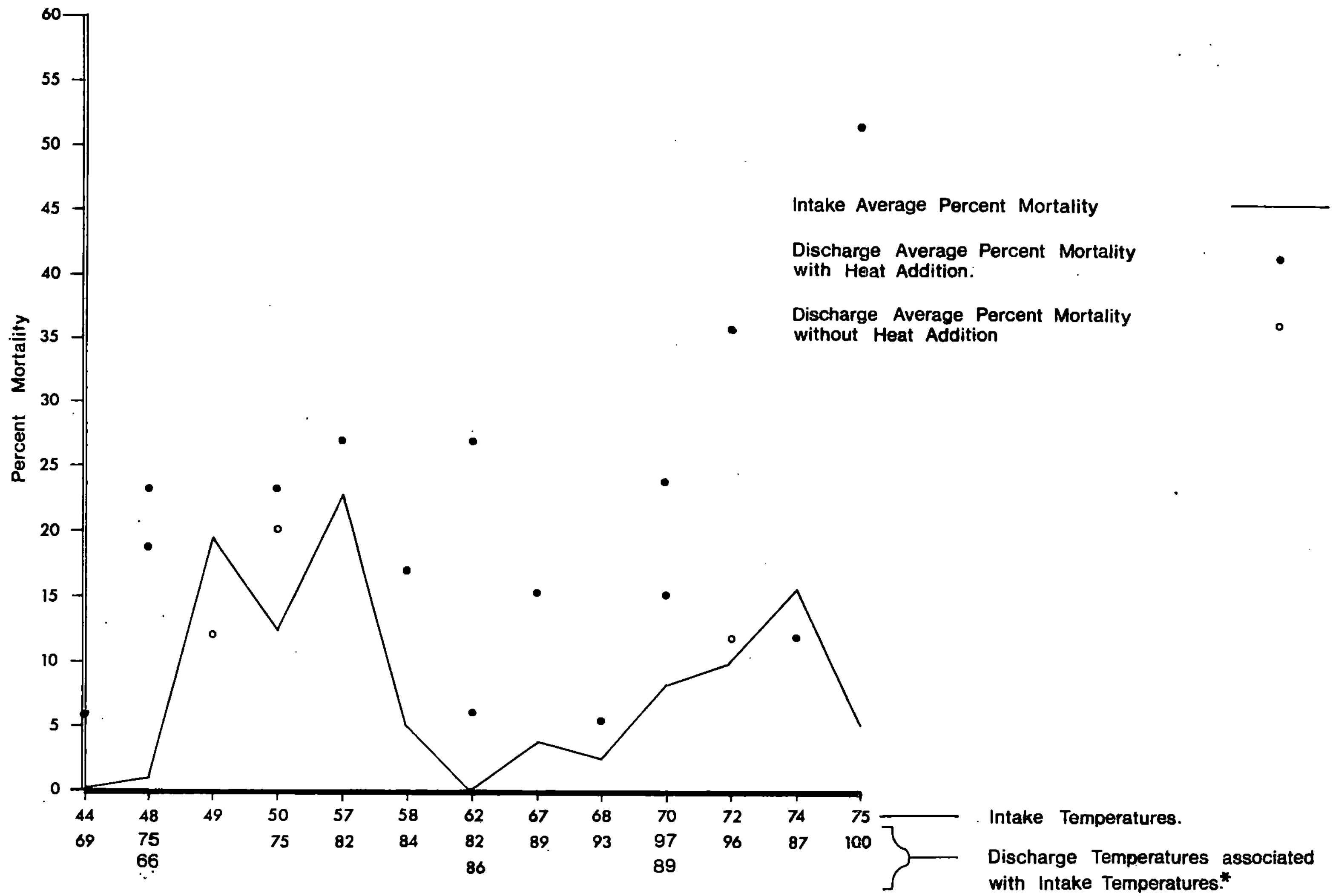


Figure B-11

Average Percent Mortality for Rotifers for Intake Samples, Discharge Samples without Heat Addition, and Discharge Samples with Heat Addition.

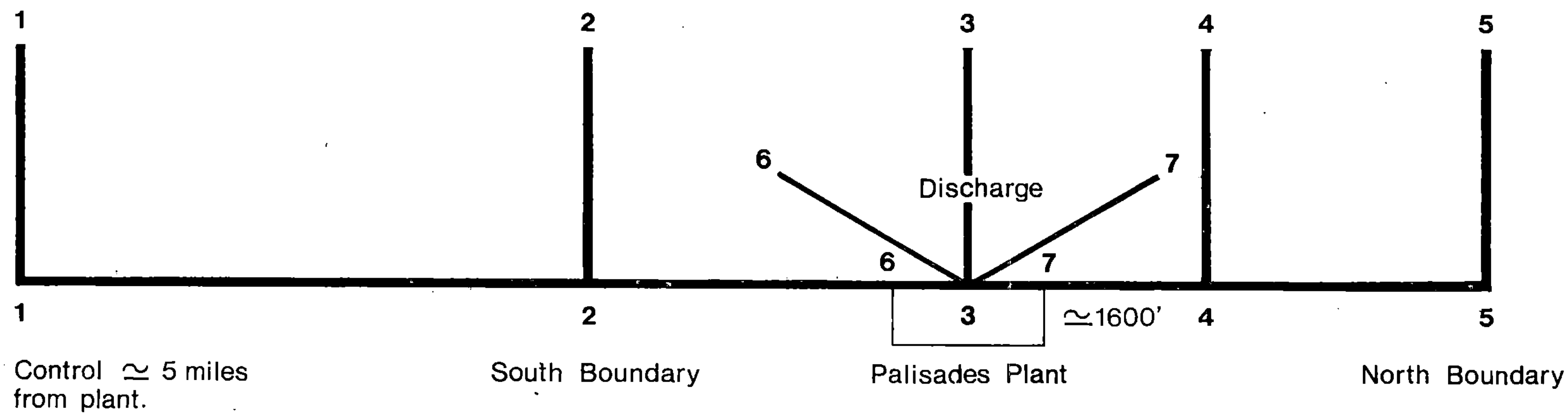


*Discharge Temperatures Associated With The Highest Percent Mortalities Are Listed First And So On In Decreasing Order.

Figure B-12

Palisades Plant,

Macrophyte Survey of Diving Locations.



SECTION C

BENTHIC INVERTEBRATES

BENTHIC INVERTEBRATES

The benthic sampling stations were sampled four periods of the year (May, June, August and October) during each preoperational year, 1968 to 1971. Samples were collected during corresponding periods after the plant began operation, and the results were initially compared to the preoperational conditions by use of bivariate control charts. Only those stations where significant changes were identified through the control chart analysis were studied in 1974. A discussion of the 1974 survey results is included along with copies of the pertinent charts in Appendix C. The overall results of the statistical comparisons are summarized in the following paragraphs.

May postoperational benthic sampling was conducted only in 1973. The comparison with the May preoperational condition is shown in Table C-1. The May 1973 results indicated that no significant changes had occurred that could be attributed to the heated effluent. Oligochaete, sphaeriid and amphipod densities were within the expected fluctuations which would occur from year to year. Changes occurred in chironomid population densities but they were not restricted to stations lying within the influence of the plume and were probably due to natural causes.

Based on the spring sinking plume observations discussed in Section A, warmed water would have touched bottom from the discharge to about 1/4 mile offshore. The plumes which were measured would have affected nearshore areas on the D-line. Other early spring plumes were often deep and their influence would have been felt by the macroinvertebrates in the vicinity of the plant. These plumes apparently did not have any deleterious effects on the benthos as no significant changes were recorded on the May control charts for the stations lying close to the discharge.

Table C-2 summarizes the June control chart comparisons for 1972, 1973 and 1974. Only two groups of organisms showed significant changes in densities, and these were at stations in at least 30 feet of water, one mile offshore from the discharge. Chironomids exhibited significant changes in density at C-1 and sphaeriids were similarly affected at F-1. Large numbers of young occurred in the sphaeriid samples from C-1 and F-1 but returned to normal densities by August. The chironomid density at C-1 was high in June 1973 and in June and August 1974; two genera, Polypedilum and Chironomus being responsible. When these organisms were studied separately at each station, ignoring the communities at other stations in the same depth group, the increases in density at C-1 and F-1 were not statistically different from the densities which had occurred during the preoperational period. It may be that the areas represented by C-1 and F-1 are becoming more favorable habitats for certain of the chironomids and sphaeriids, though analysis of the percent organic carbon did not indicate that this was so. The oligochaete and amphipod densities at C-1 and F-1 remained within natural fluctuations.

Table C-3 summarizes the August control chart comparisons for 1973 and 1974. All the communities in less than 50 feet depth lay within ranges which could be accounted for by natural fluctuations, except for the chironomid densities discussed in the previous paragraph.

Table C-4 summarizes the October control chart comparisons for 1972 and 1973. Three groups of organisms showed significant changes in density. The oligochaetes at stations lying southwest of the discharge 20 to 30 feet deep had significant increases both in 1972 and 1973. Chironomid densities indicated possible changes in inshore stations within half a mile of the discharge in 1972, but were within the bivariate control limits the following year. Sphaeriid densities showed significant decreases at the 30 to 50 foot depths in October 1973. The June 1974 densities at the same group of stations also showed significant change, but as an increase. The August densities lay within the control limits and the previously noted changes were only of short duration.

The majority of significant changes in density, as shown by control charts, occurred at stations C-1 and F-1 in the 30 to 50 foot depth range situated one mile from the discharge. The affected organisms were chironomids and sphaeriids, and the changes were present in the months of June and August for chironomids and in June and October for sphaeriids. In addition, oligochaete densities were significantly different from preoperational densities at stations southwest of the discharge, in depths of 20 to 30 feet.

The Mann-Whitney test,[1] a nonparametric procedure which makes no assumptions about the normality of the population distributions, has been used to determine where there have been significant increases or decreases in the postoperational population densities of individual organisms. The results of this analysis are tabulated in Table C-5.

Eleven different organisms showed significant increases and 10 showed decreases between the population densities of pre- and postoperational years. These included 17 species found in the following major taxonomic groups: Chironomids, sphaeriids, gastropods, oligochaetes, and platyhelminthes.

There were a larger number of significant increases (20) at stations situated within one mile of the discharge, than at stations more than one mile distant (9). The reverse was true for significant decreases in population densities, only 8 were recorded for the closer stations and 22 decreases for the more distant ones. No changes were of a very high magnitude and diversity remained fairly similar during the study. There has been no overall tendency for increases in density to occur after the plant began operations, so the observed significant increases in the benthos at individual stations are not considered to be of major importance.

Cladocera and Ostracoda underwent half the significant increases at the stations closer to the discharge. These are usually planktonic in habit and were not caught regularly by the grab. An examination of plankton numbers which would more likely be the community where the cladocerans and ostracods occur, showed large fluctuations in the numbers of these organisms.

Four crustacea showed changes: Pontoporeia hoyi, Mysis, Eurycercus, and an ostracod. The ostracod was originally identified as Candona (Cypridae), but this could not be confirmed in all the surveys. As the organism formed a minor component of the community, it was identified only to Order in most of the surveys. Eurycercus sp. (Cladocera) and the unidentified ostracod are small and fairly mobile. Relatively few individuals were present in the samples and the reliability of the Ponar grab to consistently catch these small crustaceans is in doubt because of their mobility. Four of the seven stations where density increases occurred, however, were within a half mile of the discharge and the other three were all within the same general direction from the discharge on the B and C grid lines.

Increases in Eurycercus were present at H/2, C/2, D/2, F/2, C-1, C-2 and I-5, stations with water depths ranging between 15 and 50 feet. They were situated directly offshore of and to the northwest of the discharge except for I-5, which was five miles south. The ostracods appeared for the first time in samples collected at B-1, C/2, and CN2 during postoperational surveys. They appeared in June 1972 at B-1 and C/2 and June 1973 at CN2. They were not present in the October samples at the above stations but were present then in low numbers at some of the other stations. Ostracods increased significantly over preoperational levels at F/2 and C-1. All but I-5 and CN2 were Inner control chart stations which could have been affected by the plume.

Very little information on the water quality requirements of Eurycercus and ostracods could be found, though they are known to tolerate quite a wide range of ecological factors.[2] Ostracods are usually only a minor element in the diet of fish, while Cladocera occur more frequently in the diet of both young and adult fish.

The density of Pontoporeia hoyi (Amphipoda) populations increased significantly at only one station, G-2, but decreases occurred at A-2, I-5 and CS1. A-2 and I-5 are fairly shallow and do not provide a suitable habitat for P. hoyi. CS1 was the deeper of the two south control stations, 17 miles distant, a situation very different from I-5 and A-2, which were much closer inshore. None of these stations could be expected to be directly influenced by the thermal plume.

A number of amphipod control charts had postoperational points lying outside the control limits, but changes in density were occurring at both Inner and Outer stations or Outer stations alone and there were no significant changes indicated for Inner groups for any particular month. Station G-2, where the Mann-Whitney test indicated a postoperational significant increase in density, was in the group of stations with depths of over 50 feet. These chart stations were not considered critical when considering the effects of a heated effluent, as they were all at least two miles distant from the discharge.

An analysis of the June biomass of the amphipods at the five stations composing the south quadrant control chart was conducted to determine whether populations at stations within the plume were exhibiting a change in size as well as numbers. No significant differences were found between the means of the preoperational and postoperational biomass (Appendix Ca).

Mysis, which is not an endobenthic organism, was not caught very frequently in the grab, and when caught was present only in very low numbers. It has the capability of avoiding the grab by means of a backward escape movement. *Mysis* showed a significant increase over the preoperational density at one station (F-5) which would not receive any direct thermal effect. The organism was most frequently caught at deeper stations in the Donald C. Cook Plant survey(3) and in summer rarely occurred near the shore, as it is a stenotherm requiring cooler temperatures. The best means of capture for *Mysis* is the epibenthic sampling sled, but this gear was not utilized in the Palisades survey.

Amnicola (Gastropoda) showed a significant increase in numbers at three stations, F-1, H-2 and F-2. It decreased significantly at B-1 and I-5. The thermal requirement of one species of *Amnicola* (*A. limosa*) was found in the literature, but this cannot be directly related to the Palisades situation as the gastropod was only identified to genus.(4) An optimum temperature of 18°C was given and this was never exceeded during the postoperational sampling periods at any of the stations where changes had occurred. Another snail to show changes was *Valvata*, which decreased significantly at C-2 and CN1. Both molluscs were present in low numbers during the survey and were not found at every sampling period.

Of the sphaeriids (Pelecypoda), both *Pisidium* and *Sphaerium* showed some significant changes. *Sphaerium* increased significantly at H-2 and *Pisidium* at C-5 and F-5, two of the deepest stations. There were significant decreases in the *Sphaerium* populations at C-5 and CS1. *Pisidium* decreased significantly at H-2, C-2, CS1, B-1, C/2, A-2 and I-5. Significant changes in population density were indicated in some of the control charts which included a few of the above stations. In constructing the bivariate control charts, organism density for the specific month represented on the chart was used. The Mann-Whitney test incorporated the density for a specific organism for all the pre- and postoperational surveys at one station only, thus significant differences will not always be correlated for the same organism when comparing the results of the two methods of analysis. Changes which were indicated as significant by both types of analysis were at Stations H-2 (in June 1973 and October 1972 and 1973) and B-1, C/2 (in August 1973), where significant decreases occurred. A large increase in sphaeriids occurred at Inner stations in June 1974 but this increase was only significant for this month in 1974 alone, and over the whole postoperational period there were no significant changes at the stations represented by the control chart.

Molluscs are sensitive to temperature changes, and if the plume was having an adverse effect on the benthic region, much larger changes in the population of these organisms, especially at stations close to the discharge, would have occurred. It should be noted that the B and C lines, however, were also mentioned in the discussion of the Cladocera and Ostracoda.

The third group of organisms used in the control charts, the chironomids, showed considerable species preference for various depth ranges. The generally dominant chironomid in each depth range is shown in the following table:

Dominant Chironomid	Water Depth (ft)
Chironomus	< 13
Chironomus and Cryptochironomus	13 to 26
Cryptochironomus	23 to 47
Prodiamesa bathyphila	50 to 70
P. bathyphila and Procladius	60 to 70
Heterotrissocladius, (Paracladopelma, P. bathyphila)	95

The chironomids had a few significant changes in the density of individual genera from preoperational levels. Significant decreases occurred in the populations of Cryptochironomus at I-2 (13 ft) and I-5 (28 ft), both lying south in fairly shallow water and at least two miles from the discharge. Cryptochironomus increased at C-2. Chironomus decreased significantly at A-2 (23 ft), E/2 (24 ft), H-1 (25 ft), and CS1 (70 ft); none of the stations were close together in a particular section of the sampling grid. They all had water depths of 25 feet or less except CS1. Chironomus was dominant at stations with depths up to 26 feet and Cryptochironomus at depths between 13 and 47 feet. The populations at the shallower stations were never large and could be affected by wave action. The bottom temperatures at E/2, also the nearest to the discharge, were very similar to nearby stations during the sampling periods.

Heterotrissocladius, dominant at the deepest stations in the survey, showed a significant decrease at F-5. This genus is usually found in oligotrophic waters and its decrease may indicate increasing eutrophic conditions. Procladius decreased in numbers and did not appear in any of the postoperational samples at CS1. It is usually associated with eutrophic conditions, so that increased eutrophy could not have been the cause of its disappearance.

Significant increases were indicated in Cladotanytarsus populations at D/2, F/2, H-1 and CN2. This genus was absent from all the samples at D/2, F/2 and CN2 before June 1972 (but not from the whole survey grid). It was present in the June samples only after this date and was not present in the samples in October. Cladotanytarsus was present in low numbers in June 1968 at H-1. It was also found intermittently in samples from the Campbell Plant near Holland about 40 miles north of Palisades. Paracladopelma, dominant at the deeper stations, increased at C-5, F-5, and A-1. It was first present in samples from A-1 in June 1972 and was recorded in subsequent June samples. It begins emerging in July, so immature specimens would be too small for retrieval in October. The genus was present only in low numbers at other shallow stations, so may have been previously missed by the grab at A-1.

The only significant increase in chironomid numbers indicated by the control charts was in the 30 to 50 foot depth range for June 1973 and 1974 and in August 1974. Statistical analysis of the pre- and postoperational June data

by the Mann-Whitney test indicated that the June results were caused by a significant increase in Polypedilum at C-1, but when all the surveys were examined, the increase in Polypedilum was not significant. The October control chart had the postoperational results lying within the control limits.

In August 1974, the large increase in chironomid density at 30 to 50 feet was caused by Chironomus, but over the whole postoperational survey period, this increase was not statistically significant.

Changes in the various chironomid populations occurred at stations both close to and at some distance from the discharge, and were not confined to one specific station or area of the sampling grid. All the chironomid genera found at Palisades were also recorded in the Donald C. Cook Plant surveys[3] and also showed quite large seasonal and annual variations in density.

None of the oligochaetes in the samples from the following stations were analyzed in detail: B/2, H/2, A-1, I-1, I-2 and E/2. The control charts for these stations did not indicate any significant changes. Oligochaetes at stations where changes in population density had been indicated by control charts were analyzed in detail so that the Mann-Whitney test could be applied to individual species.

Only Potamothrix moldaviensis (Tubificidae) showed any significant changes in density. This species increased at F/2 and H-1, two stations lying in the south quadrant of the sampling grid. The largest increase at F/2 was in June 1974 and at H-1 in October 1972 and June 1974. The percent organic carbon showed an increase between 1971 and 1973 and may have contributed to the increase. Potamothrix moldaviensis is associated with eutrophic conditions found in the southern part of Lake Michigan but not in the open water.[5]

Of the total counts of oligochaetes, significant decreases were shown at A-2, A-5, I-2, I-5 and C-2. These were all control chart Outer stations except C-2, an Inner station in the group with depths greater than 50 feet. Direct comparisons cannot be made with the control charts as they deal with a particular month and with a number of stations grouped together. The changes in the grouped communities of worms may show an increase for one or more particular months, such as October 1973, but the Mann-Whitney would indicate no change when all the samples for the postoperational period were used in the calculations.

Two organisms which were not sampled regularly showed a significant change in density at two stations. The Neorhabdocoela (Platyhelminthes) decreased significantly at C-1 and the Planariidae (Platyhelminthes) decreased significantly at C-5. These organisms do not preserve well, requiring special fixatives, and were not identified in detail. The water quality tolerances of the Platyhelminthes are wide and unless the species are known, they cannot be used as indicators. Very little attention was paid to them in the Palisades survey because of the very low numbers found in the samples.

Besides density changes, benthos diversity variations also occurred over the sampling grid. Increases in diversity occurred in the June postoperational samples at Inner stations between 30 and 50 feet lying west of the

discharge on the C and F lines and at stations lying northwest of the plant in 20 to 30 feet of water. Diversity at corresponding stations lying southwest of the plant showed a decrease to have occurred. June diversities at the greater depths were more stable, possibly reflecting a more constant environment, more isolated from the wave and temperature changes which are felt in the shallower inshore zones, though October diversities at all depths remained within the control chart limits for 1972 and 1973.

The significant changes in density and diversity, shown by the bivariate control chart and Mann-Whitney methods of analysis, are summarized in the following table by relating the number of stations where changes occurred to distance from the discharge. They are also illustrated in Figure C-1.

Discharge (miles)	Number of stations with Significant Changes in The Benthic Population	Total No. Of Stations
> 5	3	4
5	4	4
2	6	6
1	5	6
0.5	6	7

If the thermal effluent was directly related to the community changes, the number of stations affected should increase as the distance from the discharge decreased. It should be noted that only four 5-mile stations were sampled and changes occurred at all four of them.

The conclusion to be drawn from the benthos survey program is that no direct thermal effects are apparent in the benthic communities, but some indirect effects may be present. Statistically significant increases and decreases have occurred in some of the organism groups but they are not all concentrated in any one area and may reflect the general process of eutrophication which is occurring in Lake Michigan. The Palisades area of Lake Michigan does not provide a very good habitat for benthos and does not support a diverse and numerous benthic community.

Crayfish

During the fish impingement studies, in 1972 and 1973, a benthic invertebrate, the crayfish (Orconectes propinquis), was found among the fish sluiced off the traveling screens. A total of 4,768 crayfish was impinged and the majority of these were alive when sluiced off the screens. Like the fish, O. propinquis showed seasonal movement into the area of the intake. Figure C-2 shows the monthly totals for this species as they appeared in the screen count. Scuba diving observations near the intake showed this species to be numerous under the rip-rap surrounding the intake crib, indicating the intake crib and associated rip-rap acted as a habitat for the crayfish.

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TABLE C-1
SUMMARY OF MAY 1973 BENTHOLOGICAL CONDITIONS
USING BIVARIATE CONTROL CHARTS

DEPTH RANGE (ft.)	INNER STATION LOCATION	OLIGOCHAETES	SPHAERIIDS	CHIRONOMIDS	AMPHIPODS
0-20	1/2 mile from discharge			I	
20-30	1/2 to 1 mile NW of discharge	NC	NC	I	NC
20-30	1/2 to 1 mile SW of discharge	NC	NC	I	NC
30-50	1 mile offshore of discharge	NC	NC	I	NC
50+	2 miles offshore	NC	NC	NC	NC

Key	
NC	The density lies within the control chart limits.
I	The result lies outside the control limit. Changes have occurred at both Inner and Outer stations or at Outer stations only which lie beyond the influence of the plume.
E	Significant changes have occurred at Inner stations.

Summary
NC - 13
I - 4
E - 0

TABLE C-2
SUMMARY OF JUNE BENTHOLOGICAL CONDITIONS
USING BIVARIATE CONTROL CHARTS

DEPTH RANGE (ft.)	INNER STATION LOCATION	OLIGOCHAETES			SPHAERIIDS			CHIRONOMIDS			AMPHIPODS			DIVERSITY INDEX		
		'72	'73	'74	'72	'73	'74	'72	'73	'74	'72	'73	'74	'72	'73	'74
20 to 30	1/2 to 1 mile NW of discharge	NC	NC	-				NC	NC	NC	NC	NC	NC	I	NC	I
20 to 30	1/2 to 1 mile SW of discharge	NC	I	NC	NC	NC	NC	NC	NC	NC	NC	I	NC	I	I	E
30 to 50	1 mile offshore of discharge	NC	NC	I	NC	I	E	NC	E	E	NC	NC	NC	I	I	E
50+	2 miles offshore	NC	NC	-	NC	NC	-	I	I	-	NC	NC	-	NC	NC	-

Density	Diversity
NC = 31	NC = 2
I = 6	I = 1
E = 3	E = 2

NC = The density lies within the chart control limits.
I = The result liew outside the control limit. Changes have occurred at both Inner and Outer stations or at Outer stations only which lie beyond the influence of the plume.
E = Significant changes have occurred at Inner stations.

TABLE C-3
SUMMARY OF AUGUST BENTHOLOGICAL CONDITIONS
USING BIVARIATE CONTROL CHARTS

DEPTH RANGE (ft.)	INNER STATION LOCATION	OLIGOCHAETES '73	OLIGOCHAETES '74	SPHAERIIDS '73	SPHAERIIDS '74	CHIRONOMIDS '73	CHIRONOMIDS '74	AMPHIPODS '73	AMPHIPODS '74
20 to 30	1/2 to 1 mile NW of discharge	NC	-	NC	-	NC	NC	NC	I
20 to 30	1/2 to 1 mile SW of discharge	NC	I	I	NC	I	NC	NC	NC
30 to 50	1 mile offshore of discharge	NC	NC	NC	NC	I	E	NC	NC
50+	2 miles offshore	E	-	NC	-	I	-	I	-

Summary

NC = 17
I = 7
E = 2

NC = The density lies within the chart control limits.
I = The result lies outside the control limit. Changes have occurred at both Inner and Outer stations or at Outer stations only which lie beyond the influence of the plume.
E = Significant changes have occurred at Inner stations.

TABLE C-4
SUMMARY OF OCTOBER BENTHOLOGICAL CONDITIONS
USING BIVARIATE CONTROL CHARTS

DEPTH RANGE (ft.)	INNER STATION LOCATION	OLIGOCHAETES '72	OLIGOCHAETES '73	SPHAERIIDS '72	SPHAERIIDS '73	CHIRONOMIDS '72	CHIRONOMIDS '73	AMPHIPODS '72	AMPHIPODS '73	DIVERSITY INDEX '72	DIVERSITY INDEX '73
0 to 20	1/2 mile from discharge	NC	NC	-	-	E	NC	NC	NC	NC	NC
20 to 30	1/2 to 1 mile NW of discharge	NC	NC	NC	NC	NC	I	NC	I	NC	NC
20 to 30	1/2 to 1 mile SW of discharge	E	E	NC	NC	NC	NC	NC	I	NC	NC
30 to 50	1 mile offshore of discharge	NC	I	I	E	I	NC	I	I	NC	NC
50+	2 miles offshore	I	NC	I	NC	I	NC	NC	NC	NC	NC

Key	
NC	The density lies within the control chart limits.
I	The result lies outside the control limit. Changes have occurred at both Inner and Outer stations or at Outer stations only which lie beyond the influence of the plume.
E	Significant changes have occurred at Inner stations.

Summary

NC - 23
I - 11
E - 4

Summary - Diversity

NC - 10

Table C-5: Significant changes in density between pre- and post-operational years for individual organisms as determined by the Mann-Whitney test

Stations Within Influence of Plume (Based on Control Charts)	Significant Increase	Significant Decrease
H/2	Eurycercus (Cladocera)	
B-1	Ostracoda*	Pisidium (Sphaeriidae) Amnicola (Gastropoda)
C/2	Eurycercus (Cladocera) Ostracoda*	Pisidium (Sphaeriidae)
D/2	Eurycercus (Cladocera) Cladotanytarsus (Chironomidae)*	
F/2	Eurycercus (Cladocera) Ostracoda Cladotanytarsus (Chironomidae)* Potamothrix moldaviensis (Oligochaeta)	
C-1	Eurycercus (Cladocera) Ostracoda Neorhabdocoela	
F-1	Amnicola (Gastropoda)	
C-2	Eurycercus (Cladocera) Cryptochironomus (Chironomidae)	Pisidium (Sphaeriidae) Valvata (Gastropoda) Oligochaeta
F-2	Amnicola (Gastropoda)*	
G-2	Pontoporeia hoyi (Amphipoda)	
E/2		Chironomus (Chironomidae)

* Indicates new appearance or disappearance of organism.

Table C-5: (continued)

Stations Within Influence of Plume (Based on Control Charts)	Significant Increase	Significant Decrease
H-1	Cladotanytarsus (Chironomidae) Potamothrix moldaviensis (Oligochaeta)	Chironomus (Chironomidae)
Stations Used As Control Stations Beyond Immediate Influence of Plume		
A-1	Paracladopelma (Chironomidae)*	
A-2		Pisidium (Sphaeriidae) Pontoporeia hoyi (Amphipoda) Chironomus (Chironomidae) Oligochaeta
A-5		Oligochaeta
I-2		Cryptochironomus (Chironomidae) Oligochaeta
I-5	Eurycercus (Cladocera)	Pisidium (Sphaeriidae) Amnicola (Gastropoda) Pontoporeia hoyi (Amphipoda) Cryptochironomus (Chironomidae) Oligochaeta
H-2	Sphaerium (Sphaeriidae) Amnicola (Gastropoda)	Pisidium (Sphaeriidae)
C-5	Pisidium (Sphaeriidae)	Sphaerium (Sphaeriidae) Planariidae

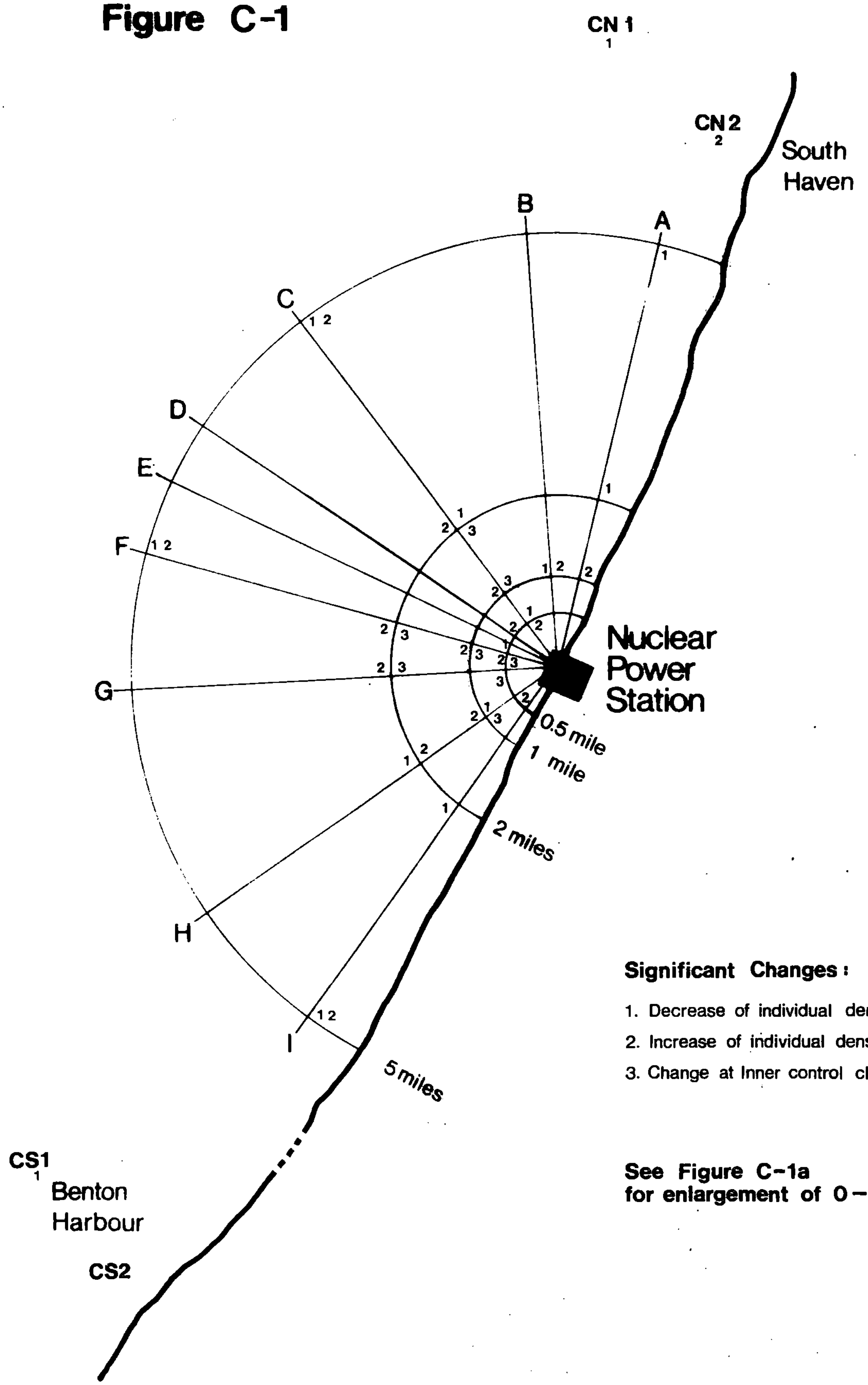
* Indicates new appearance or disappearance of organism.

Table C-5: (continued)

Stations Used As Control Stations Beyond Immediate Influence of Plume	Significant Increase	Significant Decrease
F-5	Pisidium (Sphaeriidae) Mysis (Amphipoda)	Heterotrissocladius (Chironomidae)
CN2	Ostracoda* Cladotanytarsus (Chironomidae)*	
CN1		Valvata (Gastropoda)
CS1		Pisidium (Sphaeriidae) Sphaerium (Sphaeriidae) Pontoporeia hoyi (Amphipoda) Chironomus (Chironomidae) Procladius (Chironomidae)*

* Indicates new appearance or disappearance of organism.

Figure C-1

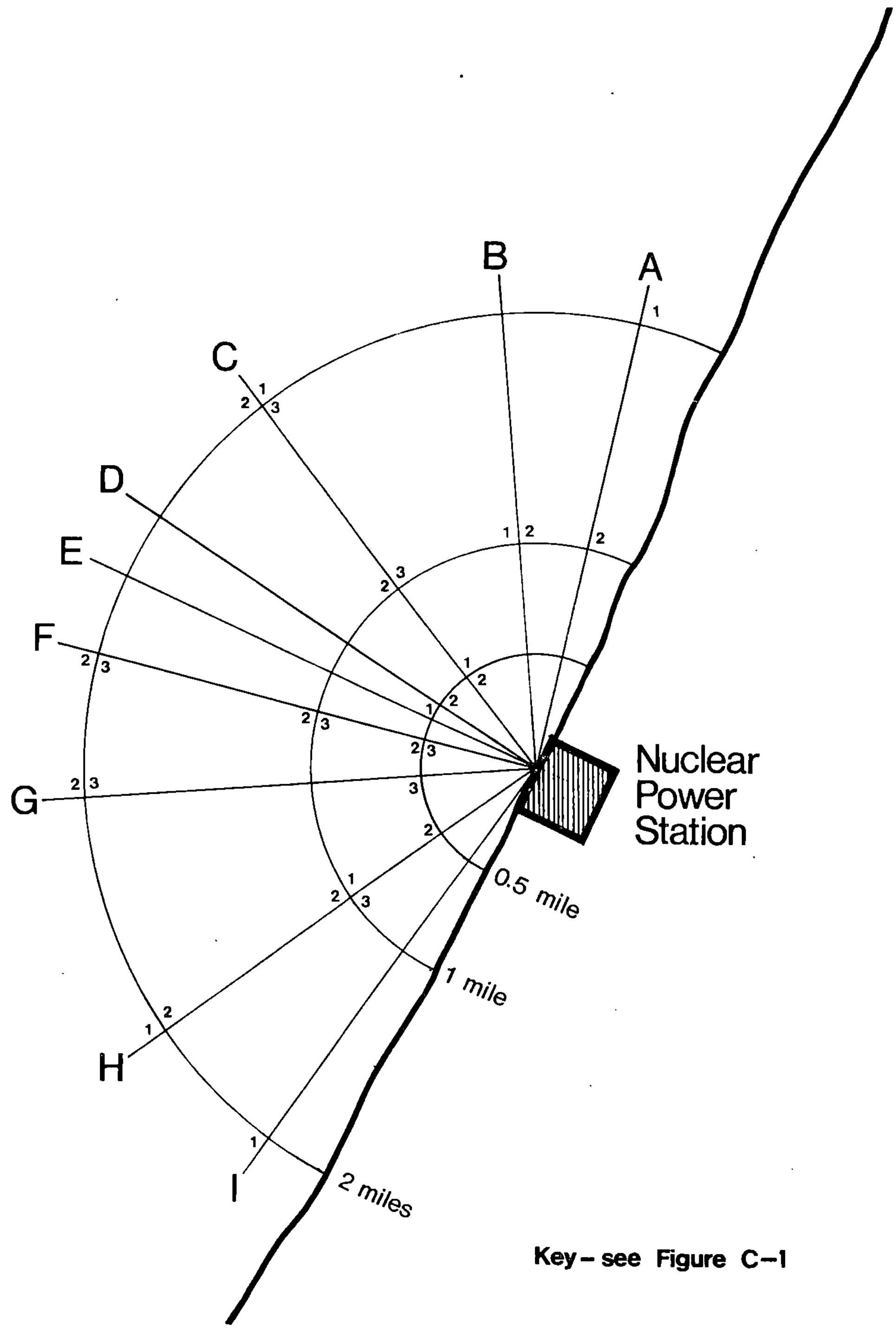


Significant Changes:

1. Decrease of individual densities.
2. Increase of individual densities.
3. Change at Inner control charts.

See Figure C-1a for enlargement of 0–2 miles.

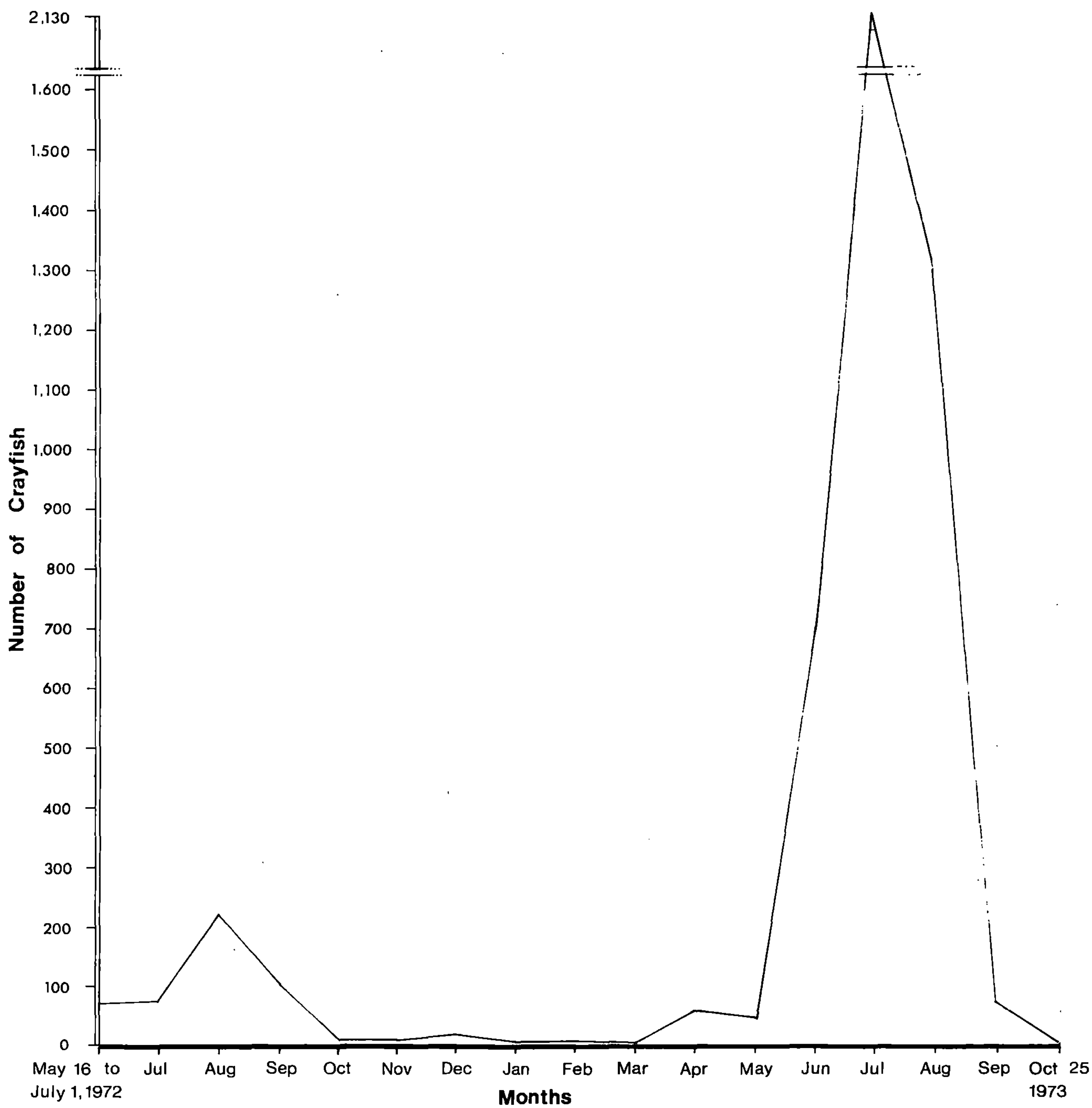
Figure C–1a



Key – see Figure C–1

Figure C-2

Total Number of Crayfish, Orconectes propinquis, **Observed on the Traveling Screens.** **May 16, 1972 to October 25, 1973.**



SECTION D

FISH

FISHERIES SURVEYS

The preceding sections discussed the effects of the thermal discharge from the Palisades Plant on the lower trophic levels of Lake Michigan, primarily the benthos and plankton. Important as these lower life forms are to the overall ecosystem, it is the next trophic level, the fish, which has the most direct relationship to man.

This section of the report summarizes what has been learned about the effects of the heated discharge from the Palisades Nuclear Plant on the fish of adjacent Lake Michigan.

The first part of the following discussion briefly summarizes the results of fisheries studies by Michigan Department of Natural Resources(1) and Consumers Power Company. These two groups conducted the most detailed fisheries surveys on site. Following this, each major species encountered is considered in terms of relative abundance, population structure, seasonal abundance, entrapment, and overall ecology as established by research conducted thus far.

A total of 57 species of fish was observed during the Palisades Plant study program and they are listed in Table D-1. It should be noted that sampling programs were somewhat inclined towards sampling the littoral zone off Palisades, and results must be interpreted with this fact in mind.

Other studies and reports relevant to an interpretation of the observations made at Palisades are also incorporated into this summary.(2)

Fisheries Surveys at Other Similar Locations

Studies of the fish populations near the Donald C. Cook Nuclear Plant in 1972 indicated that the vast majority of fish in the area belonged to a relatively small number of species.(3) Five species (in order of highest abundance), spottail shiner (Notropis hudsonius), alewife (Alosa pseudoharengus), rainbow smelt (Osmerus mordax), yellow perch (Perca flavescens), and trout-perch (Percopsis omiscomaycus), made up more than 98 percent of all fish captured. Capture methods included gill nets, seines, and trawls. Johnny darter (Etheostoma nigrum), white sucker (Catostomus commersoni), longnose sucker (C. catostomus), lake trout (Salvelinus namaycush), chinook salmon (Oncorhynchus tshawytscha), rainbow trout (Salmo gairdneri), emerald shiner (N. atherinoides), and longnose dace (Rhinichthys cataractae), made up the next 1.7 percent, while the remaining 0.3 percent consisted of 16 additional species, all in relatively low abundance. Thirty-six different species had been taken through 1972.

Maximum fry abundance in the shallow zone near the Cook Plant occurred in August and September, and consisted primarily of spottail shiners, alewives, and smelt. Fish eggs found in benthos samples were most abundant at depths greater than 9.1 m (30 ft) and were identified as yellow perch eggs.

Fisheries surveys in 1972 and 1973 at the Ludington Pumped Storage Power Plant produced data very similar to that obtained from the Cook surveys.(4) Once again, a small number of species accounted for a large percentage of the

catch. Yellow perch, alewife, rainbow smelt, spottail shiner, and white sucker, account for 91.4 percent of the gill net catch in 1973. Other major species sampled in 1972 and 1973 were longnose suckers, lake trout, and round whitefish (Prosopium cylindraceum). Seine catches showed a prominence of smelt, alewife, and spottail shiner. Young-of-the-year alewives accounted for the largest number sampled, particularly near the plant. Trawl tows produced eleven different species, mostly alewives. A total of thirty-two species were sampled by these methods. Many minor species ($<$ 30 individuals/year) were caught, and among these the following were considered to be important; chinook salmon, coho salmon, brown and rainbow trout, lake whitefish (Coregonus clupeaformis), and bloater (C. hoyi).

Industrial Bio-Test Laboratories, Inc conducted laboratory studies which considered the effects of water temperature fluctuations on various Lake Michigan fishes[5]. Responses which they investigated included performance, survival, and behavioral reactions. This study was conducted with reference to the heated discharges from Commonwealth Edison Company's Zion and Waukegan generating plants on the west side of Lake Michigan, opposite Palisades. Several general observations were made from this study. First, the more heat-sensitive species were those which normally inhabit the deep, cooler waters of Lake Michigan during the summer, thereby isolating them from maximum temperatures during summer months. Second, avoidance temperatures were well below heat shock levels in all species tested (i.e., alewife, lake trout, brown trout, brook trout, chinook salmon, coho, yellow perch, golden shiner, largemouth bass, rainbow smelt, and slimy sculpins), except yellow perch, and generally approximated or were slightly below upper lethal temperatures. Third, all species tested preferred temperatures above ambient during at least some time of the year and may therefore be attracted to the plumes. These preferred temperatures were consistently well below avoidance temperatures.

MDNR Fisheries Surveys at Palisades

The Institute for Fisheries Research of the Michigan Department of Natural Resources conducted preoperational surveys of the fish stocks in Lake Michigan near the Palisades Nuclear Power Plant beginning in the summer of 1968. These surveys continued when the plant was operational.

A total of forty species of fish was sampled by a combination of gill net, seine, and trawl techniques. The dominant species in the gill net catch were alewives (53.2 percent) and perch (40.0 percent). The seine catch was dominated by alewives, spottail shiners, longnose dace, and trout-perch, and the trawl catch by smelt (shallow zones) and bloaters (deeper zones). Summary tabulations of data from the Department of Natural Resources project report[1] are included in Appendix D.

Gill net catches of perch and alewives, the two most numerous species, were compared statistically for the periods before and after plant start-up. No significant difference could be demonstrated at the 90 percent level of confidence. In an attempt to determine the effect of the thermal plume on species distribution, a paired 't' test was used to compare catches of the four most numerous species caught both in and out of the plume. No significant differences could be demonstrated. Species tested were yellow perch, alewife, longnose sucker, and white sucker. However, it was pointed out that the nets were bottom nets, whereas the plume was a floating plume and therefore did not necessarily encompass the nets.

Seine catches of spottail shiners, longnose dace, and trout-perch were also statistically (paired 't' test) compared to determine if a change in the inshore populations had occurred following the introduction of the thermal discharge in 1972. No significant differences were found in the mean catches. Changes in catch had occurred, but variability was such that a change of 50 to 60 percent was required in order to be significant.

Smelt, alewife, and trout-perch dominated the trawl catches, however, the data were not sufficient for the results to be related directly to plant operation. Some apparent effects of plant operation were observed as a result of the fish sampling program.

The spawning period for approximately 1/3 of the perch collected in the vicinity of the plant in 1973 appeared to have been advanced by as much as three to four weeks, from the normal early-June period, to mid-May. It was suggested that this advanced spawning period was a reflection of the warmer spring water temperatures due to the thermal discharge from the plant.

Samples of salmonids taken in and out of the plume indicated that lake trout and brown trout may have been attracted to the plume, whereas salmon were not. Sample numbers, however, were very small. It should be pointed out, however, that due to the seasonal nature of the sampling program, the presence or absence of fish species between late October and early May was not monitored.

It is also worth noting that water temperatures along the beach, as monitored by the Michigan Department of Natural Resources during their seining operations over the six year period, were not noticeably greater during plant operation in 1972. Data indicate that all 1972 seining temperatures were equalled or exceeded in preoperational years at comparable times of the year. On the other hand, 1973 nighttime temperature maximums along the beach seining area did exceed previous maximums by 4° to $9^{\circ}F$ (2.2° to $5^{\circ}C$).

The Department of Natural Resources report(1) concludes by stating that there were no statistically significant differences in fish abundance before and after the presence of a thermal plume. It is careful to point out, however, that catches of all major species declined in 1973, with the exception of the spottail shiner. Perch declined despite an overall increase in the lake population, their growth rate was depressed (possibly due to a strong 1969 year class), and their spawning period seemed to be slightly advanced. Appendix D includes information on gill net catches of perch in the form of percent age composition, average length and calculated weight by sex, and instantaneous rates of growth.

Consumers Power Surveys

Consumers Power Company fishery surveys during 1972 and 1973 included seine, trawl, and gill net sampling. In addition, fish entrapment on the plant intake screens was monitored between 23 January 1972 and 25 October 1973.

Seining operations were carried out at five areas along the shoreline. The total catch results were normalized by year and are graphically displayed in Figures D-1 and D-2. The species catch data are included in Appendix D. Seining operations at stations in heated water yielded considerably higher catches than at stations in non-heated zones. It was concluded that the warm discharge water acted as an attractant to alewives, carp, spottail shiner, trout, salmon, and centrarchids. Large numbers of alewife, carp (Cyprinus carpio), and spottail shiner were observed visually in the discharge canal. Fish abandoned the discharge area as their temperature preferenda were exceeded.

Trawling results, graphically displayed on a normalized basis on Figures D-3 through D-6, also indicated that the discharge acted as an attractant to fish. Highest relative catches were obtained directly off the discharge point, but only when there was a discharge, either heated or non-heated. Smelt and alewives were the prominent species. Trawls were at the 10-foot depth, below the direct influence of the plume. The largest trawl collections were obtained where the water was more turbid, indicating this method of fish collection may not have captured truly representative samples of the fish populations. Similar difficulties were also encountered in seining operations. The trawl species catch data are included in Appendix D.

Additional gill net data were collected in 1973 from the general discharge area and the immediate vicinity of the discharge. The data were organized according to species caught and the temperature at the time of fishing and are presented in Table D-2. Nets set in different temperature ranges indicated that perch were tolerant of temperatures up to 90°F (32.2°C) and possibly higher. The range up to about 70°F (16°C) appeared to be the maximum tolerable limit for the salmonids, which indicated a preference for the 50° to 60°F (10° to 16°C) range. The gill net data, together with seine and trawl data, indicate that many fish species, normally occurring in the area off the Palisades Plant, inhabited the area of the discharge at some time during the year. The reason for the attraction of these fish may have been temperature and/or current, but the attraction seemed definite. It should be noted that the discharge, because of its attraction to fish, provided an active sport fishery during spring, early summer and fall.

The plant intake was monitored for fish eggs and larvae between May 1972 and October 1973. Of the eggs collected (Table D-3), most were unfertilized. It is believed that some of these eggs were expelled by fish entrapped in the intake.

Thirty-six larvae were collected from the intake water and consisted of the following: smelt (13), sculpin (9), alewife (12), and perch (2). These represent the most numerous fry in the area as monitored by the U. S. Bureau of Sport Fisheries and Wildlife in 1972 and 1973.

Fish entrapped in the plant's intake system were collected by the 3/8 inch mesh traveling screens. The total numbers and percentages of each species and the periods of greatest impingement are shown in Table D-4. Figures D-7 and D-8 graphically present the seasonal variation of total numbers and percents of fish collected. Appendix D contains summary tabulations of each species by reporting period with the total weight of each species captured. Between 23 January 1972 and 25 October 1973, a total of 653,890 were

impinged. Dominant species were as follows: Alewife (58.6 percent), spottail shiner (7.2 percent), slimy sculpin (27.5 percent) and perch (4.2 percent). By comparison, few game fish were entrained. These included salmonids (158), coregonids (553), smelt (7,633) and pike (18). Over 50 percent of the impinged fish were observed to be physically damaged when taken off the screens. Many of the species appeared on the screens on a seasonal basis. The seasonal entrapment of alewives, perch, spottail shiners, and slimy sculpins is shown graphically in Figures D-9 through D-12.

On August 15, 1972 and October 14, 1973, scuba divers descended in the vicinity of the intake to observe fish movement and measure current velocities at the intake crib.

Observations at the time of the survey, and other times, indicated many fish inhabit the crib and actively swim in and out of the structure. Perch, alewife, longnose suckers and white suckers were observed by the hundreds in the area of the crib. The rip-rap around the base of the crib provided habitat for crayfish, johnny darter, and slimy sculpin, which accounts for the presence of these organisms in the screen counts. Appendix A shows the results of current measurements during both surveys.

MAJOR FISH ENCOUNTERED

Coho salmon - *Oncorhynchus kisutch*

Coho salmon were successfully introduced into Lake Michigan in 1966, and have since become an important sport fish. Consequently, stocking efforts were intensified in many areas. A fish stocking program, beginning in 1970, included the planting of over one million coho in southeastern Lake Michigan.

Coho salmon approach parent streams in September and generally remain in the stream until early winter, by which time spawning activities are completed. During the remainder of the year, January to September, the salmon occupy the deeper areas of the lake, avoiding temperatures in excess of 60°F (16°C). The optimum preferred temperature of the adults is approximately 55°F (13°C). In early spring, when Lake Michigan is considerably below this temperature, these fish may have been attracted to the Palisades plume when temperatures were near 55°F (13°C). Coho were collected in the immediate area of the discharge in temperatures up to 70°F (21°C). They constituted a very small percentage ($<$1.0 percent) of the catch at all times. Numbers impinged were also $<$ 1.0 percent. Experiments indicate(5) that coho salmon will avoid temperatures exceeding 70°F (21°C).

Coho are stream spawners, so the plume should have had no effect on egg hatching dates or larvae and fry development. After one to two years in the parent stream, they migrate out into Lake Michigan as smolts. At this time, they may be subject to plume exposure. However, the numbers sampled and personal communications with Michigan Department of Natural Resources indicate that the smolt remain for some time in the general vicinity of the mouths of their parent streams and then gradually migrate into the deeper waters of Lake Michigan, where they enter a period of rapid growth.

Overall abundance of this species must be considered low in the immediate area of the discharge. Almost all specimens caught or impinged were young fish, 6 to 12 inches long, and were no doubt a result of Michigan Department of Natural Resources' stocking program. Catches at two other power stations on the east shore of Lake Michigan, Ludington and Cook, also indicated relatively low numbers of coho inhabiting these areas.

Chinook salmon - *Oncorhynchus tshawytscha*

The chinook salmon is another non-endemic species, currently being introduced into the Great Lakes. Stocking efforts in Lake Michigan began in 1967, and included the introduction of approximately 800,000 chinook salmon yearlings in two rivers flowing into southeastern Lake Michigan, the St Joseph River and Kalamazoo River. The closest, St Joseph River, is approximately 20 miles from the plant site.

All fish sampling programs at Palisades indicated the presence of relatively low numbers of chinook. Six years of gill netting by Michigan Department of Natural Resources yielded only five individuals. All were young fish, and believed to be from the stocking efforts. The majority were impinged during the early summer period, before the young migrate to the deeper waters of the lake and become piscivorous.

Similar results were obtained during the Ludington studies[3]. Eleven (11) chinook fingerlings were caught during seining operations. All had migrated down the Lake Michigan shoreline from stocking areas north of the plant. Some shoreline movement is to be expected as a result of these stocking efforts. However, data do not indicate any large mortalities or impingement of either juvenile or adult chinook salmon at the Palisades Plant.

Steelhead - *Salmo gairdneri*

Like the chinook and coho, this species is not endemic to Lake Michigan, but like these two Pacific salmon, the rainbow trout is a logical introduction in view of the large numbers of forage fish, especially alewives, available to them. Stocking efforts through 1974 in southeastern Lake Michigan totaled approximately 800,000, of which 95 percent were the "steelhead" variety. The steelhead introduced were spring-spawning stock; these fish enter streams from late October to early May, and spawn from late December to late April.

Observations at the plant discharge indicated that steelhead were attracted to the heated discharge. This attraction was most evident in December 1972 and January 1973, when many steelhead were observed in the discharge area and considerable numbers were caught by sports fishermen. When plant shutdown occurred, the fish immediately left the area, with no apparent harmful effects. Gill netting efforts by Consumers Power Company indicated that steelhead movements in and out of the discharge area, particularly during later fall and early spring, coincided with plant start-ups and shutdowns. Gill net data indicated that steelhead were present in the discharge area up to temperatures of 70°F (21°C). Maximum abundance was observed in the 51° to 60°F (10° to 16°C) range. This coincides with the preferred temperature (55.4°F, 13.2°C) and preferred spawning temperatures (50° to 60°F 10° to 16°C)

of this species. No steelhead were taken in gill netting over a six year period by Michigan Department of Natural Resources personnel. Their efforts were not concentrated at the outfall and the absence of steelhead from the catch records supports the observation that the fish are attracted only to the immediate discharge area.

Discharge temperatures approximating the 50° to 60°F (10° to 16°C) range occurred in the period from December to February, and some attraction could be expected at that time. However, data do not indicate any deleterious effects of the discharge on this species.

Some impingement of younger age classes, during movements along the shoreline, can be expected. Impingement data indicate this occurrence to be rare. Adult steelhead were observed avoiding a warm discharge in the Columbia River during their summer spawning migration. The gill net data suggest a similar reaction at Palisades, once their temperature preferendum has been exceeded.

Considered together, the three anadromous salmonids frequenting the Palisades area, namely coho salmon (O. kisutch), chinook salmon (O. tshawytscha), and steelhead (S. gairdneri), cannot be judged as endangered due to operation of the Palisades Nuclear Plant[6]. Despite considerable stocking efforts near the Palisades Plant (i.e., Black, St Joseph, and Kalamazoo Rivers), very few (71) were impinged during the study period and very few were sampled by gill net, trawl, or seine. Provided the thermal plume did not impede migration up the spawning streams previously named, which seems highly unlikely, no threat to this stage of the reproductive cycle exists. A factor which must be considered is the effect the Palisades facility had on the forage species, particularly alewives and smelt, upon which these salmonids feed so extensively. This will be considered in a later section of this report. Also, with steelhead, the effects of increased exploitation by the sports fishery on concentrations of fish associated with the plume area on the regional stock might be considered.

Lake trout - Salvelinus namaycush

Although lake trout stocks throughout the Great Lakes are still much below previous levels, the recent sea lamprey control program and subsequent trout re-stocking efforts justify an evaluation of the species with regard to the possible effects of power generating facilities such as Palisades.

Results of gill netting operations off Palisades by Michigan Department of Natural Resources between 1968 and 1973 yielded a total of 46 lake trout. Of these, 33 were caught in the first four preoperational years and the remaining 13 in the first two operational years. Thus there would seem to be a slight decrease in abundance since the plant became operational, if populations were assumed to be constant over this period.

In its final environmental statement relating to the Palisades facility, the U. S. Atomic Energy Commission cited test fishing carried out near Palisades in late 1971 by the U. S. Bureau of Sport Fisheries and Wildlife[7], which indicated that some lake trout may be spawning in the area. Spawning occurs in October to November over rocky or rubble areas, often shoals, in depths less than 120 feet in the Great Lakes[8]. At present, most

lake trout production occurs in hatcheries but, as stated above, some natural reproduction is believed to occur in southeastern Lake Michigan. Lake trout eggs are demersal and therefore should be in no danger from the intake structure. Should some spawning take place in the Palisades area, incubating eggs may periodically be exposed to a sinking plume. However, the frequency of spawning in the immediate area is questionable. A total of 86 lake trout was impinged during the study period and the majority of these fish were observed between January and March, which suggests winter attraction to the plume rather than an effect on spawning activities, which occurred two months earlier. In addition, a series of cruises in 1972 off Palisades to obtain fry samples did not reveal any lake trout fry present in the area, as only perch, smelt and alewife fry were collected.

Sampling programs off the Ludington pumped storage facility indicated that the few lake trout caught preferred the deeper waters. Most were caught in October to November, which also suggests that their presence was related to spawning activity.

The success of the lake trout in future years in Lake Michigan will largely be a function of lamprey control, commercial fishing pressure, and food availability. Like the anadromous salmonids, lake trout feed largely on alewife and smelt, but may also feed extensively on sculpin in Lake Michigan.

Brown trout - *Salmo trutta*

Brown trout did not constitute a large percentage of the fish sampled at Palisades. This species has a higher optimal growth temperature range (65° to 75°F, 18° to 24°C)[8] than the coho, chinook, rainbow or lake trout. It would appear that brown trout are attracted to the plume area but are not readily impinged, as only one specimen was taken from the traveling screens during the study period.

Seining efforts at Palisades by both Consumers Power Company and Michigan Department of Natural Resources yielded small catches ($<$ 1.0 percent), although total seine catch (approximately 20) exceeded the gill net catch.

Fishing efforts at nearby power facilities yielded comparable numbers of brown trout. Brown trout sampled by all methods in 1972 at the Donald C. Cook Plant totaled seven [3]. Most were taken at night, by gill net. At the Ludington facility, 68 brown trout were sampled by seine, and 12 by gill net.[4]

Brown trout captured by seine at the Palisades Plant were all one year old fish. No brown trout fry, eggs or larvae were collected at Palisades and results indicate that present stocks in the area are very small.

Lake whitefish - *Coregonus clupeaformis*

Historically, the lake whitefish was a major component of the commercial fishing catch in northern Lake Michigan. Several factors, notably the sea lamprey and over-fishing, contributed to its catastrophic decline, with all-time low levels being reached in the late 1950's in Lake Michigan. In the 1960's, production began to increase along with the intensity of the lamprey control program and the increase in lake trout. Lake whitefish abundance is still relatively low.

The sampling programs at Palisades, Ludington, and Cook revealed very small populations in these areas. The southern half of Lake Michigan is a marginal zone for the whitefish. No whitefish were sampled in Lake Michigan in 1972 off the Cook Plant and the U. S. Bureau of Sport Fisheries and Wildlife found none off Palisades in 1971, nor did the Michigan Department of Natural Resources in their six year gill netting program, also off Palisades. A total of 28 was impinged on the traveling screens at Palisades, the majority of them during the month of August. Most were immature fish (average weight = 0.6 lb.).

Lake whitefish normally inhabit the deep coal regions of the lake until late fall, when they move into shallow areas to spawn. Some areas off Palisades may be suitable for spawning, however, it is considered unlikely and no data exist to suggest that any of these areas are currently in use.

Round whitefish - *Prosopium cylindraceum*

Very few round whitefish have been caught off Palisades. Gill netting operations over six years yielded only six (6), and the impingement count totaled one (1). This may be a result of the benthic-feeding habits of this species, which would lessen the susceptibility to intake at Palisades.

The round whitefish inhabits the cooler parts of Lake Michigan, although not usually deeper than 150 feet. Spawning occurs in late fall, at which time this species moves into shallower water. Data collected do not indicate that the round whitefish was significantly influenced by the Palisades Plant.

Cisco - *Coregonus artedii*

Cisco or lake herring have traditionally exhibited wide fluctuations in abundance in all the Great Lakes. Cisco production was often the highest of any species in the early fishery of Lake Michigan, with major catches from the Green Bay fishery. However, like lake whitefish, the cisco population in Lake Michigan suffered a catastrophic decline, and is today considered insignificant. One of the major reasons for this decline is the competitive effect of the alewife on this shallow-water planktivore.

Fish sampling efforts at Palisades and Cook yielded very small numbers, and no cisco were caught off Ludington. At Palisades, three (3) were impinged during the first 21 months. Gill netting by Consumers Power Company near the discharge area yielded no cisco, and gill netting near the Palisades Plant in and out of the plume, by Michigan Department of Natural Resources yielded only four (4) over a six year period. Trawling and seining by both Consumers Power Company and Michigan Department of Natural Resources did not yield any cisco. Overall abundance of cisco in Lake Michigan near Palisades therefore appears to be very small.

Bloater - *Coregonus hoyi*

The bloater, largely because of its deepwater habits, did not figure prominently in any of the sampling programs off Palisades, nor on the intake screens. It represented 0.7 percent (112) of the total gill net catch by Michigan Department of Natural Resources. No bloaters were taken by gill net

in the immediate discharge area. Trawling efforts by Consumers Power Company produced a total of 28, most of which were taken off the discharge when a thermal plume was present. Trawl tows in 1969 by Michigan Department of Natural Resources produced 94 bloaters, most at the deepest levels. Tows made in 1972 did not produce any bloaters, but were not comparable, primarily because of depth and trawl differences. No bloaters were taken in seining operations by either party. Impingement totaled 521, mostly in early summer, and corresponded with peak catches by trawl and gill net.

The bloater is currently the most abundant of the remaining deepwater ciscoes in Lake Michigan, and dominates what remains of the cisco fishery(4). None of the remaining ciscoes (i.e., Coregonus nigripinnis, C. johannae, C. zenithicus, C. alpenae, C. reighardi, C. kiyi) were taken by any method, or impinged during the Palisades surveys. Their decline in Lake Michigan was largely a function of overexploitation, and need not be considered further.

Although the bloater is now common throughout Lake Michigan, its deepwater habits preclude any major influence by Palisades. Although they migrate inshore to some extent in early summer, as catch data indicate, the magnitude of the catch does not indicate any serious threat. Depth of the intake is far above their preferred depth range. Studies on larval distribution in Lake Michigan by Wells(9) indicated that larvae were most abundant at depths between 300 and 360 feet. Spawning occurs over a wide, deep depth range (120 to 300 feet)(8). It must be concluded that the bloater, because of its deepwater habits, could not be significantly influenced by the Palisades Plant. Spawning, early development and adult life stages all occur in depth zones of Lake Michigan that are out of the range of influence of the thermal plume or the intake. Relatively low catches at Ludington and Cook also substantiate this view.

Alewife - Alosa pseudoharengus

The alewife accounted for a major part of the catch by all sampling methods, and 58.6 percent by number of the total impinged fish. As discussed by Wells and McLain(2), the alewife unquestionably has had detrimental effects on native fish stocks through feeding competition and predation of young, yet as a prolific forage species it has also formed the base for the successful introduction of salmon in Lake Michigan.

Major impingement of adults occurred in April 1973 during the spawning run. Alewives were one of several species observed by the hundred in the area of the intake crib. Peak catches in gill nets were obtained in May by Michigan Department of Natural Resources. Trawling efforts by Michigan Department of Natural Resources showed a peak abundance of alewife in late July 1969, at approximately 42 feet and 72 feet, indicating that the schools were beginning to leave the shallower areas. Maximum numbers of adult alewives were taken by seine in the inshore areas during May 1970, also corresponding to the spawning run. There is little doubt that peak abundance of adults occurs in April to May, as the fish move in to spawn. Trawl tows and seining data indicated that the adults were attracted to the discharge, particularly when the plant was in operation and the discharge water warmed. An opposite response was indicated in the trawl catch for young alewives, which showed maximum abundance in the nonheated discharge.

Maximum abundance of young-of-the-year and yearling alewives occurred in late summer through fall. This was also the period of greatest impingement.

The catch and impingement data for alewives at Palisades can be directly related to their life cycle. Adults inhabit open lake water most of the year. In April, they move to shallow inshore areas to spawn. Spawning activities follow a diurnal cycle as the adults move inshore at night and offshore during the day. Seining results during the night and day strongly reflect this. Adults appeared to be attracted to heated discharges and gill net data indicated that adults frequented the discharge area in temperatures up to 80°F (27°C), although the maximum catch was at 51° to 60°F (11° to 16°C). Hatching has been shown to occur much faster at 72°F (22°C) (3 days) than at 60°F (16°C) (6 days).

Alewives mature very quickly in freshwater, males at age 2+ and females at age 3+. The species is very prolific, a ripe freshwater female can have 10,000 to 12,000 eggs. Assuming 100 percent hatching success, approximately 30 females could replace the 340,000 adults impinged during the study period or, assuming 1 percent hatching success, 3,000 females would suffice. These figures tend to oversimplify a situation which is in reality quite complex. However, they do serve to illustrate that a single stress point (Palisades) in an alewife population reproducing along many miles of Lake Michigan shoreline will not, in all probability, seriously threaten the population. Fish egg and larvae entrainment was monitored and results indicated that very few alewife larvae were being entrained in the plant's intake system. Data obtained by the US Bureau of Sport Fisheries and Wildlife during this entrainment study indicated large numbers of alewife fry, as well as perch and smelt fry, in depths of 30 feet or less. Based on the intake data it does not appear that entrainment posed a great danger to larvae.

The relative abundance of alewives at Ludington and Cook was comparable. At Ludington, alewives constituted 10.6 percent of total catch in 1973 (second most abundant) and were also the second most abundant fish sampled at the Cook Plant (32.1 percent).

The effect of the alewife on previously abundant near-shore species is not well-defined. However, the sudden increase in alewife stocks in Lake Michigan has occurred almost simultaneously with a decrease in cisco and emerald shiners. Perch and smelt have also declined, possibly due to heavy predation on their eggs and larvae during the alewife spawning runs.

Alewives are believed to be extremely sensitive to thermal shock, particularly during their spawning season. Acclimation to higher temperatures, due to a heated discharge, may increase their susceptibility. Laboratory studies[5] on several species, indicated that the alewife was the only one of the species tested which appeared to be susceptible to cold death resulting from a station shutdown and the sudden disappearance of a heated plume. These studies were carried out in relation to the Waukegan Generating Plant, on the west side of Lake Michigan, and this susceptibility was limited to a brief period in the spring. Several shutdowns of the Palisades Plant did occur during the study period; however, there was no evidence of any resulting alewife mortality.

Rainbow smelt - *Osmerus mordax*

Rainbow smelt was one of the more common species encountered during the Palisades study. Over 7,500 were impinged, mostly adults and largely during April to May 1973, during the spring spawning migration. The highest seine catch was also in May 1973. Adult smelt did not constitute a large percentage

of the gill net catch, however, this may have been a function of the mesh size fished. Smelt were more prominent in the trawl catch, particularly young-of-the-year and yearlings. Trawl and seine data indicated that they were attracted to the discharge, whether heated or non-heated. Entrainment of eggs and larvae appeared to be minimal, and it is highly unlikely that any of the eggs entrained were smelt eggs.

The smelt is an anadromous species, ascending freshwater streams in the spring to spawn. Like the alewife, it is of marine origin, having successfully adapted itself to the Great Lakes environment. Spawning sometimes occurs offshore on gravel shoals in the Great Lakes, if streams are not available or stormy weather prevails. There is no evidence of such spawning at Palisades. Impingement data indicate that the only impact of the power plant was on young and adults. Use of the discharge channel as an artificial tributary in spawning runs is considered unlikely.

Yellow perch - *Perca flavescens*

Considerable numbers of yellow perch were taken during all sampling operations, and approximately 28,500 were impinged, primarily adults. Impingement of adult perch peaked in May to June of 1972 and 1973. This peak corresponds to the spawning period for perch in Lake Michigan. Many perch were observed in the area of the intake crib during diving operations. Gill net catches by Michigan Department of Natural Resources were high (40.1 percent) and peaked in mid-summer. Gill nets set in the immediate discharge area indicated that perch were among the most thermally tolerant of any fish present. Highest trawl catches were near the discharge, when there was a heated effluent. Most perch collected by seining were young-of-the-year and yearlings, and were taken in late summer. Only two larvae were collected during the intake study.

More detailed information on yellow perch at Palisades was obtained by Michigan Department of Natural Resources during their six year study. Population age structure, growth, maturity, mortality, and spawning time were investigated. Interpretation of the data was made more difficult because of a strong 1969 class, possibly due to a cessation of commercial perch fishing in 1970. Analysis of their data revealed differences in length-weight relationships between 1973 and previous years. Female perch (all age classes) grew slower in 1972 and 1973 than in preoperational years. Mean lengths for males of all age groups were smaller in June 1973 than for the other periods. Differences in growth rate were observed, but the exact cause was uncertain. Causes of a depressed growth rate both in 1972 and 1973 could have been one, or a combination of, higher water temperature, overcrowding in the plume, high fish abundance because of high survival of the 1969 year class, and/or reduction in food availability. However, netting evidence from in and out of the plume contradicts the overcrowding theory, and similarly, higher temperatures generally result in faster growth. It was suggested that the abundance of the 1969 brood may have had a greater influence on growth rates than any other factor, including the heated effluent. There was evidence that the warmer water temperatures advanced the spawning period for perch in the discharge area by about three weeks, this being the major effect noted with reasonable certainty. Although it could not be demonstrated as statistically significant, the perch catch at Palisades in 1973 dropped, despite an overall increase in the lake population.

Yellow perch were the most abundant game fish in the Palisades area throughout the summer and fall. Commercial production has declined considerably, possible because of the alewife. Perch and alewives are closely associated temporally and spatially during spawning and the alewife is suspected of inhibiting perch reproduction, although no strong proof exists. However, the alewife decline in 1967-1968 was followed by a strong 1969 year class of perch[4]. Adults move into deeper water in the fall, and the danger of entrainment or impingement decreases. At this time, however, young perch begin to appear on the traveling screens. In relation to the adults, however, impingement of young would seem insignificant.

All shallow areas of Lake Michigan have produced commercial quantities of perch, but Green Bay is the greatest producer. Perch spawn up and down the entire shoreline, and are not noticeably concentrated off Palisades. The intake may have exerted a stress on the local population, but a lakewide effect is highly doubtful. Studies at the Cook Plant indicated that most eggs were deposited in depths between 30 and 80 feet[2]. Wells[10] found that in southeastern Lake Michigan, perch usually spawn in depths less than 40 feet, during May to June. By autumn, adults have moved to deeper zones. Studies at Ludington[4] indicated a similar pattern. The spawning period for perch off Ludington in 1973 did not change from 1972, whereas that off Palisades was somewhat advanced. This suggests the heated effluent was the factor involved.

Trout-perch - Percopsis omiscomaycus

The trout-perch was sampled at Palisades by all methods, however trawling in the near-shore waters was most successful. Impingement totaled 3,485 and occurred primarily between April and June of both 1972 and 1973, during the spawning season. Spawning in the Great Lakes occurs both in tributary streams and along the shoreline over sand and gravel bottoms[8]. The trout-perch remain in deeper waters during the day, moving into shallow shore water after dark. Most trout-perch caught were taken by daytime trawling and nighttime seining. Gill net efforts were largely unsuccessful, possibly due to the small size (3 to 5 inches) of this fish.

The trout-perch is of little direct importance to man, but is of great importance as a forage fish for many piscivorous species. It has also been suggested[11] that, because of its daily inshore-offshore movements, the trout-perch serves as a nutrient transporter. The data do not indicate if this species was attracted to the heated plume.

Slimy sculpin - Cottus cognatus

The slimy sculpin was the second most abundant fish impinged on the traveling screens. Impingement totaled 180,203 during the study period and was concentrated, as with many other species, during March, April and May. The rip-rap around the base of the intake crib provided ideal habitat for slimy sculpins, which may largely account for the presence of these fish on the screens. Very few were taken by seine (only 5 between 1969 and 1973). Six (6) were taken in trawl tows and seven (7) by gill net. The data do not indicate if the heated

discharge attracted large numbers to the general area or in any way accounted for the large numbers entrained. Normal depth distribution of this species in Lake Michigan covers a wide range (18 to 270 feet), but it occurs most commonly in depths of 120 to 240 feet[8]. As most were impinged during the spring spawning period, it appears that considerable numbers are spawning in relatively shallow depths. Fecundity of this species is relatively high - a 4-inch female may deposit 1,400 eggs[8]. Spawning habits of the slimy sculpin are not well documented in the Great Lakes and general life history is not known.

Spottail shiner - Notropis hudsonius

The spottail shiner is probably the most abundant minnow in Lake Michigan. As forecast by the U. S. Atomic Energy Commission in its final environmental statement relating to Palisades, the normal distribution of this species places it in proximity to the intake crib and impingement data verify this. Impingement peaked during early spring and late fall, especially December 1972. Data also indicate that the spottail shiner preferred the warmer discharge area. The gill net catch was low, due to the mesh sizes fished. Trawl data indicated a preference for the area 1/2 mile south of the plant, whether heated or non-heated. Seining data indicated a preference for the immediate discharge area, for both young and adults. Little information is available on temperature preferences of this species. However, seining by Michigan Department of Natural Resources indicated a preference for the 55° to 64°F (13° to 18°C) temperature range. Gill nets set in the immediate discharge area by Consumers Power Company caught 17 spottail shiners, 14 of which were in water temperatures of 51° to 60°F (11° to 16°C). Seining in temperatures exceeding 70°F (21°C) was relatively unproductive. It appears that the preferred temperature range is approximately 57° to 65°F (14° to 18°C), and when plume temperatures fall in this range, relatively high concentrations of spottail shiners can be expected.

Spawning occurs during spring and early summer. The spottail shiner is quite prolific - a two year old female may deposit over 2,000 eggs[8]. Maturation time is only one year. In view of the high fecundity and reproductive potential, approximately 200 females could replace annual impingement losses, assuming a 1 percent hatching success. Entrainment data do not indicate any significant amount of egg or larval entrainment.

Spottail shiners do not migrate over large distances. In view of this, any effect by the Palisades Plant on this species would probably be localized.

Longnose sucker - Catostomus catostomus

Both the longnose and the white sucker (C. commersoni) were caught in the sampling programs off Palisades. The longnose was consistently more abundant. Approximately 1,300 were impinged; mostly in June. Longnose suckers spawn in the spring, usually April to May, and usually in tributary streams. Tributary streams along eastern Lake Michigan doubtless act as major spawning grounds, however some lake spawning may occur in shallow areas. The high impingement rate in June may have been a result of spawning activity, as suckers follow the shoreline in search of tributary streams. Fecundity is high, ranging

from 17,000 to 60,000 eggs per female. Considering this, the magnitude of impingement loses significance. Since most reproduction occurs in tributary streams, the Palisades Plant would not influence hatching or early larval development of progeny in rivers. Lake spawning is questionable; however, eggs are demersal and would not be subject to entrainment. Sampling of the intake did not indicate any larval entrainment.

Life history of the white sucker is similar, and the same comments can be applied to this species as well. Both species are bottom dwelling, which was certainly a key factor in the low impingement figures. Gill netting data collected by the Michigan Department of Natural Resources over six years, indicated higher catches of both suckers after the plant began operations. These fish were, therefore, apparently attracted to the discharge.

Other Species

Many other species were captured during the Palisades studies, either by impingement on the traveling screens or by one of the sampling methods employed by Michigan Department of Natural Resources or Consumers Power Company. These species did not represent a large percentage of the total. This may have been due to one of several reasons, notably: (1) depth and habitat at Palisades was not favorable for a particular species; (2) Palisades is at one extreme of their zoogeographical range; (3) a species is rare due to natural or artificial (e.g., commercial fishing) reasons. In view of these factors, it was not deemed necessary to consider them in more detail.

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Table D-1: List of species collected by seining, trawling, gill netting, and impingement on the traveling screens from 1968 of the pre-operational studies to 25 October 1973 of the post-operational studies

COMMON NAME (Scientific Name)	PRE-[1] OP.	POST-[2] OP.	OBSER-VATION	SEINE	TRAWL	GILL NET	TRAVEL-ING SCREENS
Sea lamprey (*Pteromyzon marinus*)		x					x
Lake sturgeon (*Acipenser fulvescens*)		x				x	
Bowfin (*Amia calva*)		x					x
Longnose gar (*Lepisosteus osseus*)		x	x	x			
Gizzard shad (*Dorosoma cepedianum*)		x				x	x
Alewife (*Alosa pseudoharengus*)	x	x	x	x	x	x	x
Chinook salmon (*Oncorhynchus tshawytscha*)	x	x		x		x	x
Coho salmon (*Oncorhynchus kisutch*)	x	x		x	x	x	x
Brown trout (*Salmo trutta*)		x		x	x	x	x
Rainbow trout (*Salmo gairdneri*)		x		x	x	x	x
Lake trout (*Salvelinus namaycush*)	x	x		x	x	x	x
Lake whitefish (*Coregonus clupeaformis*)		x					x
Lake herring (cisco) (*Coregonus artedii*)	x	x					x
Bloater (*Coregonus hoyi*)	x	x			x	x	x

Table D-1 (continued)

COMMON NAME (Scientific Name)	PRE-OP.[1]	POST-OP.[2]	OBSERVATION	SEINE	TRAWL	GILL NET	TRAVELING SCREENS
Round whitefish (*Prosopium cylindraceum*)	x	x				x	x
American smelt (*Osmerus mordax*)	x	x		x	x	x	x
Central mudminnow (*Umbra limi*)		x					x
Northern pike (*Esox lucius*)	x	x	x	x	x	x	x
Grass pickerel (*Esox americanus vermiculatus*)	x					x	
Goldfish (*Carassius auratus*)		x	x				
Carp (*Cyprinus carpio*)	x	x	x	x	x	x	x
Longnose dace (*Rhinichthys cataractae*)	x	x		x			x
Creek chub (*Semotilus atromaculatus*)	x	x		x			
Lake chub (*Hybopsis plumbea*)		x					x
River chub (*Hybopsis micropogon*)		x					x
Common shiner (*Notropis cornutus*)	x					x	
Spotfin shiner (*Notropis spilopterus*)	x	x		x			
Emerald shiner (*Notropis atherinoides*)	x	x		x			
Spottail shiner (*Notropis hudsonius*)	x	x		x	x	x	x

Table D-1 (continued)

COMMON NAME (Scientific Name)	PRE-[1] OP.	POST-[2] OP.	OBSER-VATION	SEINE	TRAWL	GILL NET	TRAVEL-ING SCREENS
Buffalo fishes (*Ictiobus* spp.)		x	x				
Quillback carpsucker (*Carpiodes cyprinus*)	x	x		x			
Northern redhorse (*Moxostoma macrolepidotum*)		x					x
Redhorse sucker (*Moxostoma* spp.)	x	x				x	
Golden redhorse (*Moxostoma erythrurum*)	x	x		x		x	
White sucker (*Catostomus commersoni*)	x	x		x	x	x	x
Longnose sucker (*Catostomus catostomus*)	x	x		x	x	x	x
Channel catfish (*Ictalurus punctatus*)	x	x	x		x	x	x
Yellow bullhead (*Ictalurus natalis*)		x					x
Brown bullhead (*Ictalurus nebulosus*)		x				x	x
Black bullhead (*Ictalurus melas*)	x	x				x	x
Trout-perch (*Percopsis omiscomaycus*)	x	x		x	x	x	x
Burbot (*Lota lota*)	x	x		x		x	x
Brook stickleback (*Eucalia inconstans*)		x		x			
Nine-spine stickleback (*Pungitus pungitus*)		x			x		x
Slimy sculpin (*Cottus cognatus*)	x	x			x	x	x

Table D-1 (continued)

COMMON NAME (Scientific Name)	PRE-[1] OP.	POST-[2] OP.	OBSER-VATION	SEINE	TRAWL	GILL NET	TRAVEL-ING SCREENS
Mottled sculpin (*Cottus bairdi*)	x	x		x			
Largemouth bass (*Micropterus salmoides*)		x		x			
Smallmouth bass (*Micropterus dolomieui*)	x	x		x			
Black crappie (*Pomoxis nigromaculatus*)		x		x		x	
White crappie (*Pomoxis annularis*)		x		x			
Rock bass (*Ambloplites rupestris*)		x					x
Green sunfish (*Lepomis cyanellus*)		x		x			
Bluegill (*Lepomis macrochirus*)	x	x		x			
Pumpkinseed (*Lepomis gibbosus*)		x		x			
Yellow perch (*Perca flavescens*)	x	x		x	x	x	x
Johnny darter (*Etheostoma nigrum*)	x	x		x	x		x
Log perch (*Percina caprodes*)		x					x

[1] Two species collected in pre-operational surveys not collected in post-operational surveys.

[2] Twenty-five species collected in post-operational surveys not collected in pre-operational surveys.

Table D-2 Number of fish collected with 125 foot variable gill net sets at or near the mouth of the discharge, 1973 (Data from Consumers Power Company)

SPECIES	TEMPERATURE 1-4.5°C	5-10°C	10.5-15.5°C	16-21°C	21.5-26.5°C	27-32°C	33-38°C
	33-40°F.	41-50°F.	51-60°F.	61-70°F.	71-80°F.	81-90°F.	91-100°F.
Gizzard shad			3				
Alewife		36	192	12	134		
Coho				2			
Brown trout		3	13				
Lake trout		7	9				
Steelhead	3	5	18	6			
Northern pike				1			
Smelt		1	1				
Carp			5	1			2
Spottail shiner		3	14				
Channel catfish							1
White sucker		7	23	2	3		
Longnose sucker					4		
Trout-perch			1				
Burbot	2						
Slimy sculpin		1	2	5			
Perch		4		3	61		39
Bluegill							1
Black crappie		1					
TOTALS	5	68	281	32	202		43

Table D-3 Number of fish eggs and larvae collected from the intake 16 May 1972 to 17 October 1973

METHOD								
PUMP SAMPLES					SUSPENDED NET SAMPLES			
Number of Hours	Depth	Number of Eggs	Number of Larvae	Number of Gallons	Number of Hours	Number of Eggs	Number of Larvae	Number of Gallons[1]
503.5	Surface	10,456	11	362,520	1,020	2,877	5	7,737,040
259.5	Middle	20	10	186,840	257.5	45	2	1,953,223
193	Bottom	167	4	138,960	187	469	4	1,418,457
TOTALS								
956		10,643	25[2]	688,320	1,464.5	3,391	11[3]	11,108,720

1. Theoretical number of gallons passed through net, based on plant specifications.
2. Thirteen of these were smelt fry, four were sculpin larvae, and eight were alewife larvae.
3. Five of these were sculpin larvae, two were perch larvae, and four were alewife larvae.

Table D-4 Total number of fish collected from traveling screens at the Palisades nuclear power plant from 23 January 1972 to 25 October 1973

SPECIES	TOTAL NUMBER (%)	PERIOD OF GREATEST IMPINGEMENT
Sea lamprey	1 (<1.0)	-
Gizzard shad	9 (<1.0)	-
Alewife - young	42,565 (6.5)	October, 1972; October, 1973
- adult	340,774 (52.1)	April, 1973
Cisco	3 (<1.0)	-
Steelhead	16 (<1.0)	Spring
Coho salmon	26 (<1.0)	May-June, 1972 and 1973
Chinook salmon	29 (<1.0)	June-July, 1973 (young)
Lake trout	86 (<1.0)	January-March, 1973
Lake whitefish	28 (<1.0)	August, 1973
Round whitefish	1 (<1.0)	-
Brown trout	1 (<1.0)	-
Bloater	521 (<1.0)	May-August, 1972 and 1973
Smelt - young	874 (<1.0)	June-August, 1973
- adult	6,759 (1.0)	April-May, 1973
Northern pike	18 (<1.0)	October, 1973
Central mudminnow	1 (<1.0)	-
Carp	17 (<1.0)	Winter
Longnose dace	5 (<1.0)	-
Spotfin shiner	1 (<1.0)	-
Spottail shiner	46,897 (7.2)	October-April, 1973; *Dec.(esp.)
Lake chub	3 (<1.0)	-
River chub	2 (<1.0)	-
Northern redhorse	1 (<1.0)	-
White sucker	395 (<1.0)	December-January, 1973
Longnose sucker	1,294 (<1.0)	June, 1973
Channel catfish	168 (<1.0)	December-January, 1973

Table D-4 (continued)

SPECIES	TOTAL NUMBER (%)		PERIOD OF GREATEST IMPINGEMENT
Yellow bullhead	2	(<1.0)	-
Black bullhead	76	(<1.0)	April-June, 1972
Trout-perch	3,485	(<1.0)	April-June, 1973; May, 1972
Burbot	513	(<1.0)	December-March, 1973
Nine-spine stickleback	409	(<1.0)	April-June, 1972, 1973
Slimy sculpin	180,303	(27.5)	March-April-May
Rock bass	1	(<1.0)	-
Pumpkinseed	2	(<1.0)	-
Bluegill	5	(<1.0)	-
Perch - young	1,084	(<1.0)	October-December, esp. Dec. 1972
- adult	27,433	(4.1)	May-June, 1972, 1973
Logperch	1	(<1.0)	-
Johnny darter	27	(<1.0)	May, 1972, 1973
Bowfin	54	(<1.0)	February-May, 1972
Total	653,890		

LOCATION KEY TO FIGURES D-1 and D-2

Seining

Area 1 - Control area located approximately five miles south of the plant and out of the influence of the plume.

Area 2 - South boundary area located approximately one-half mile south of the discharge.

Area 3 - South of discharge area, approximately 600 feet in length going south from the discharge piling.

Area 4 - North of discharge area, approximately 600 feet in length going north from the discharge piling.

Area 5 - North boundary area located approximately one-half mile north of the discharge.

Figure D-1

Relative daytime seining catch of fish in the study areas of Lake Michigan for 1972-73

(Relative catch = catch of area / mean catch of all areas)

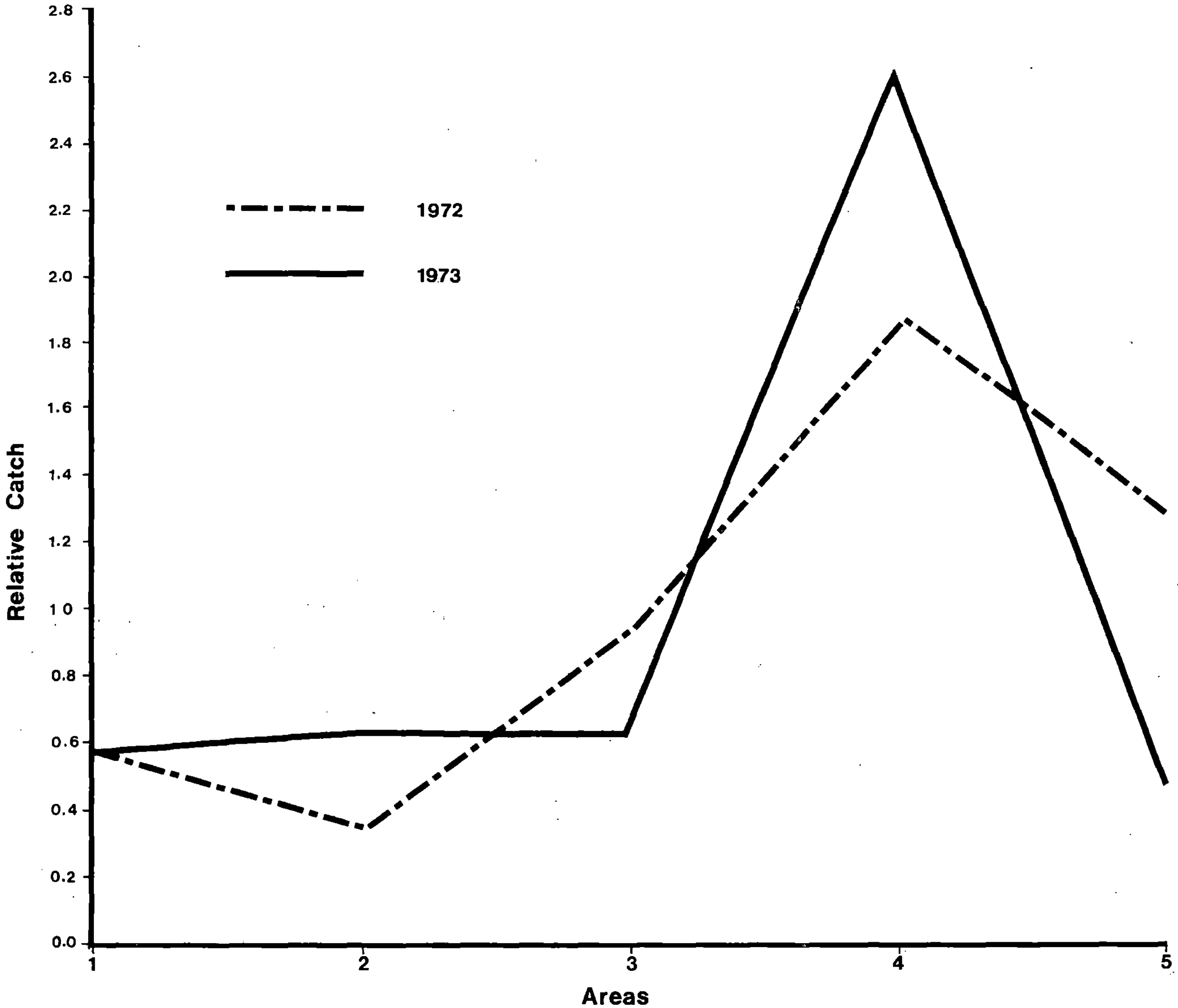
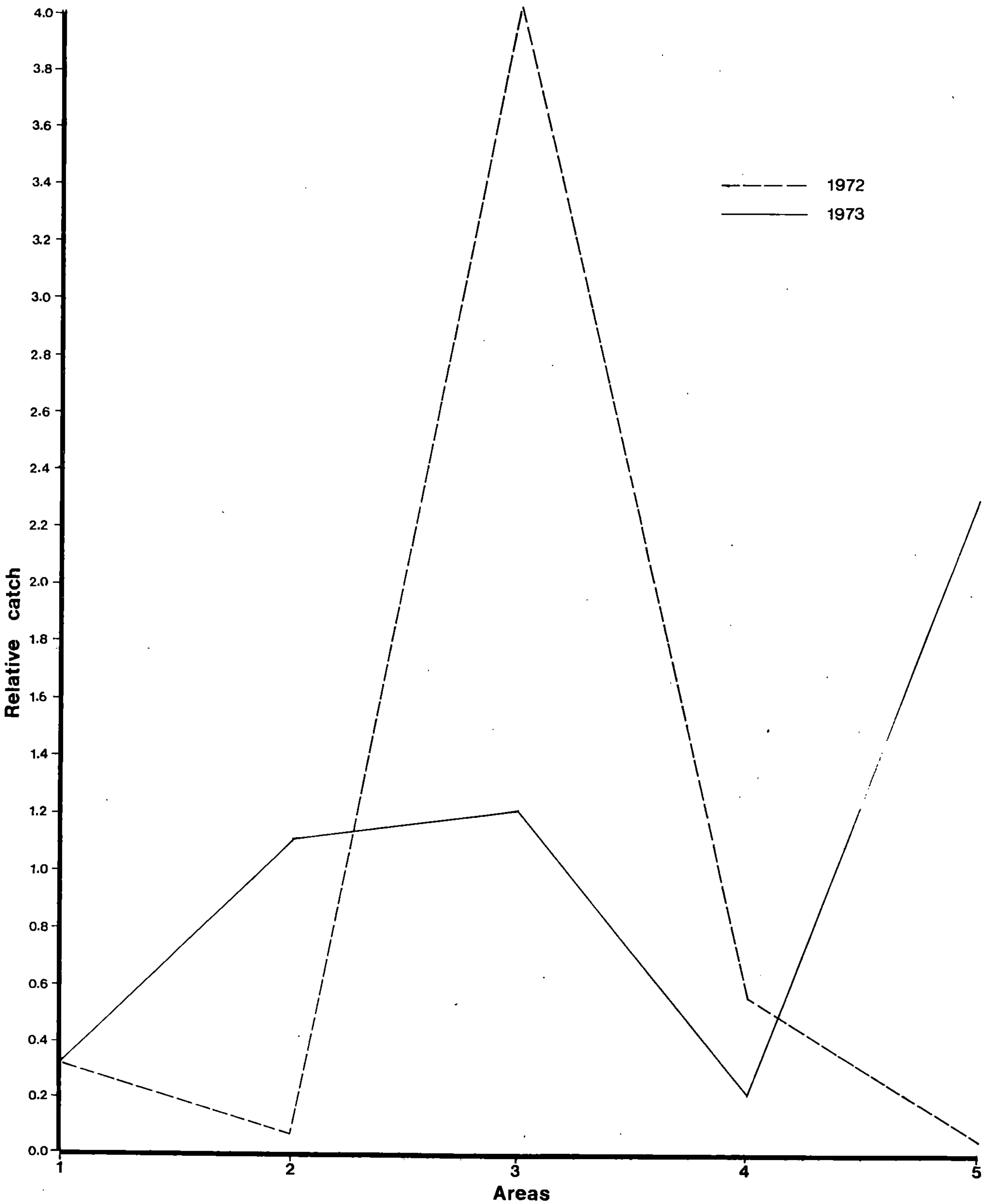


Figure D-2

Relative night time seining catch of fish in the study areas of Lake Michigan for 1972-73.

(Relative catch = catch of area / mean catch of all areas)



LOCATION KEY TO FIGURES D-3, D-4, D-5 and D-6

Trawling

Area 1 - Control area located approximately 5 miles south of the plant and out of the influence of the plume.

Area 2 - South boundary area located approximately one-half mile south of the discharge.

Area 3 - Discharge area directly off the discharge structure.

Area 4 - North boundary area located approximately one-half mile north of the discharge.

Figure D-3

Relative 10 ft level trawling catch for heated and non heated discharges for 1972-73

(Relative catch = catch of area / mean catch of all areas)

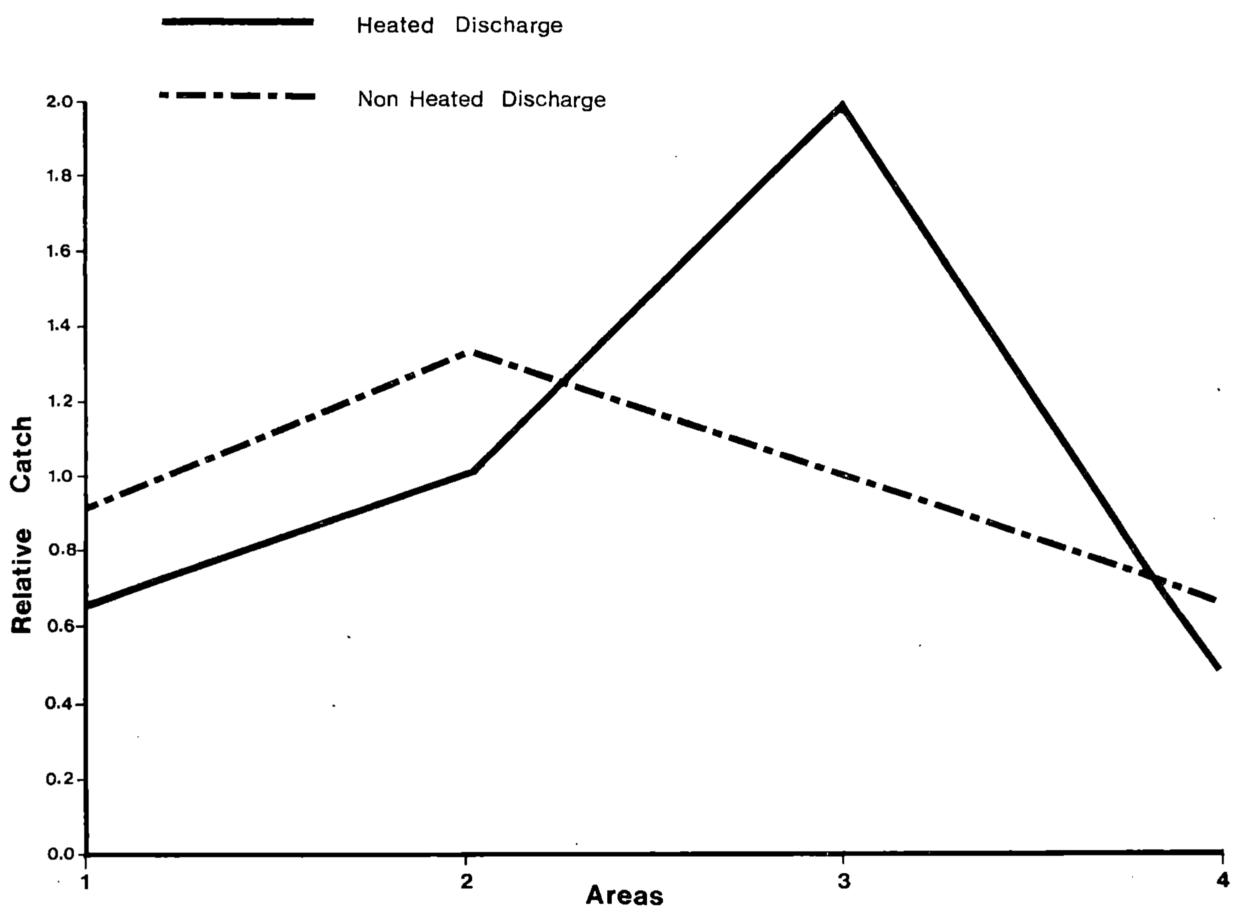


Figure D-4

Relative perpendicular trawling catch for heated and non heated discharges for 1972-73

(Relative catch = catch of area / mean catch of all areas)

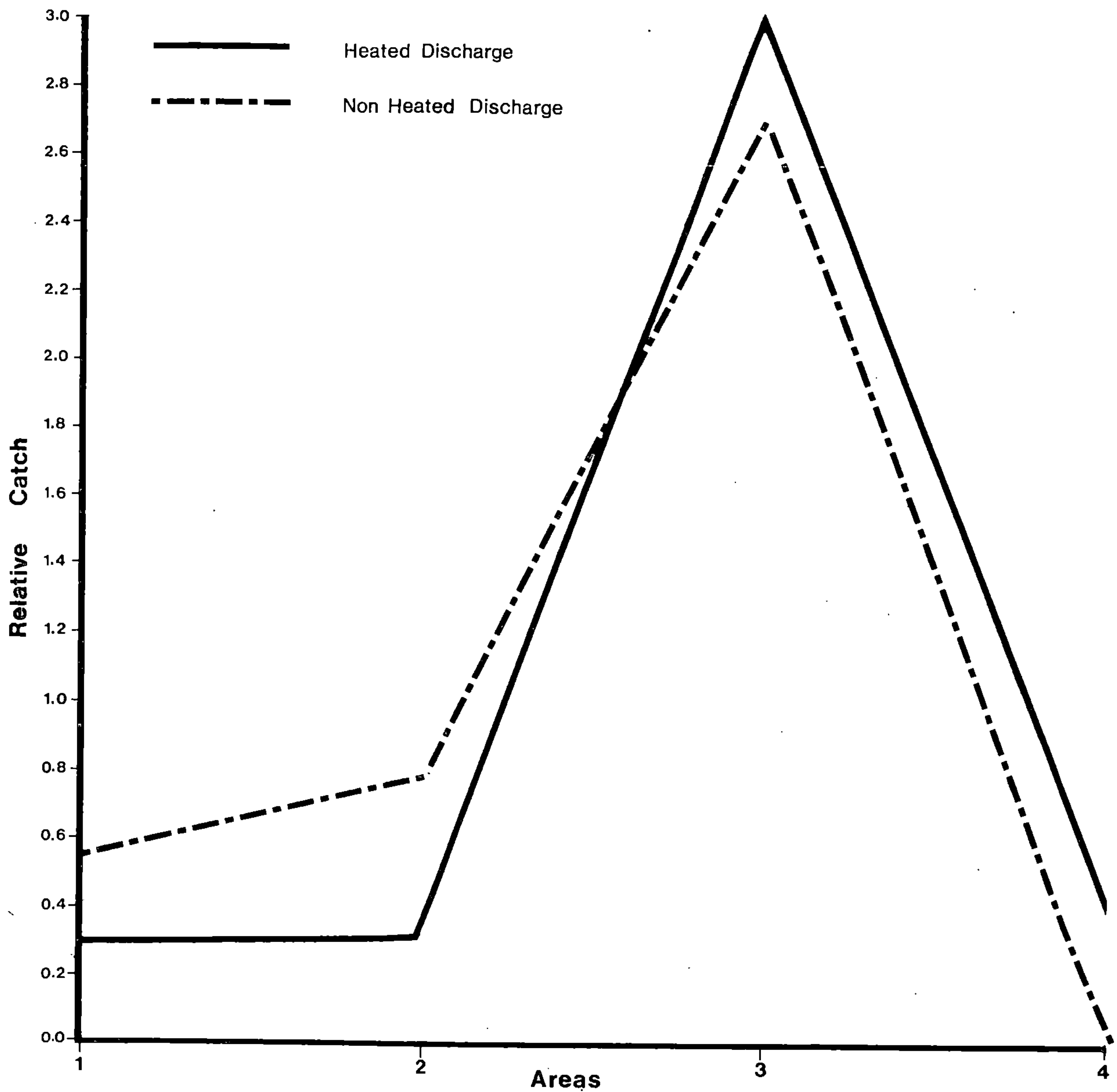


Figure D-5

Relative density of 4 species of fish collected in 10 ft level trawl tows for heated & non heated discharges

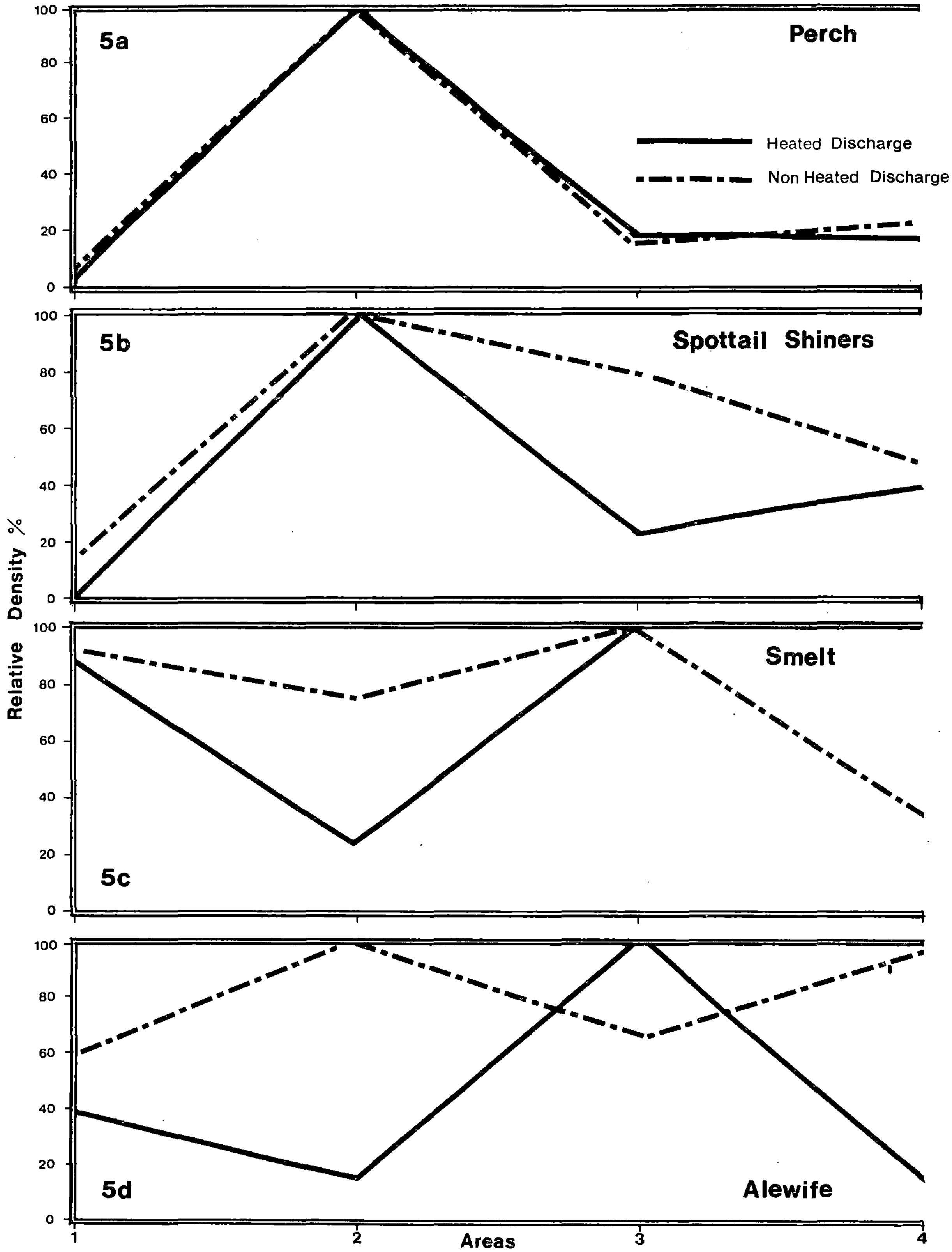


Figure D-6

Relative density of two species of fish collected in perpendicular trawl tows for 1972-73 for heated and non heated discharges.

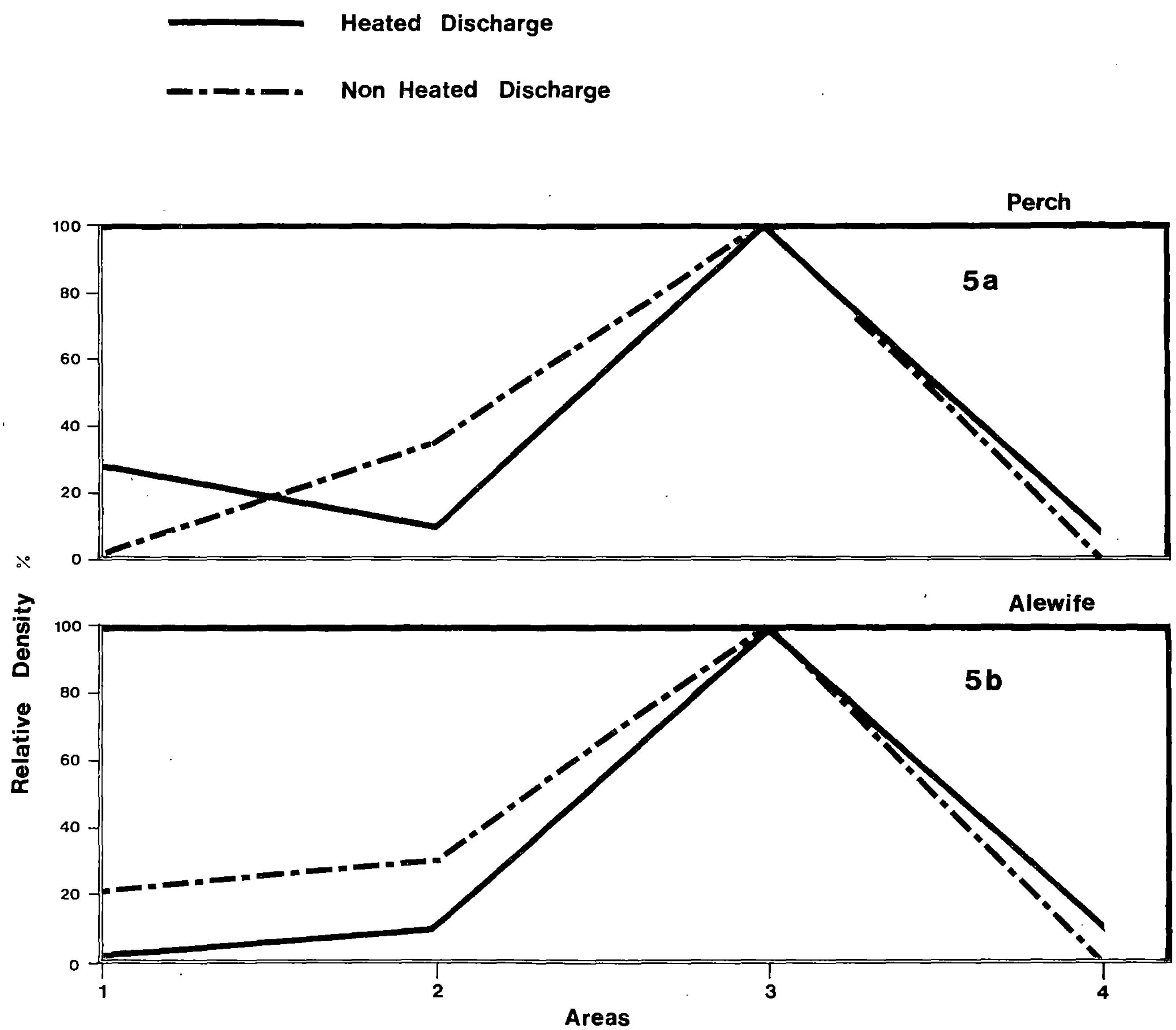


Figure D-7
Number of all fish species observed on the traveling screens
May 16, 1972 – October 25, 1973.

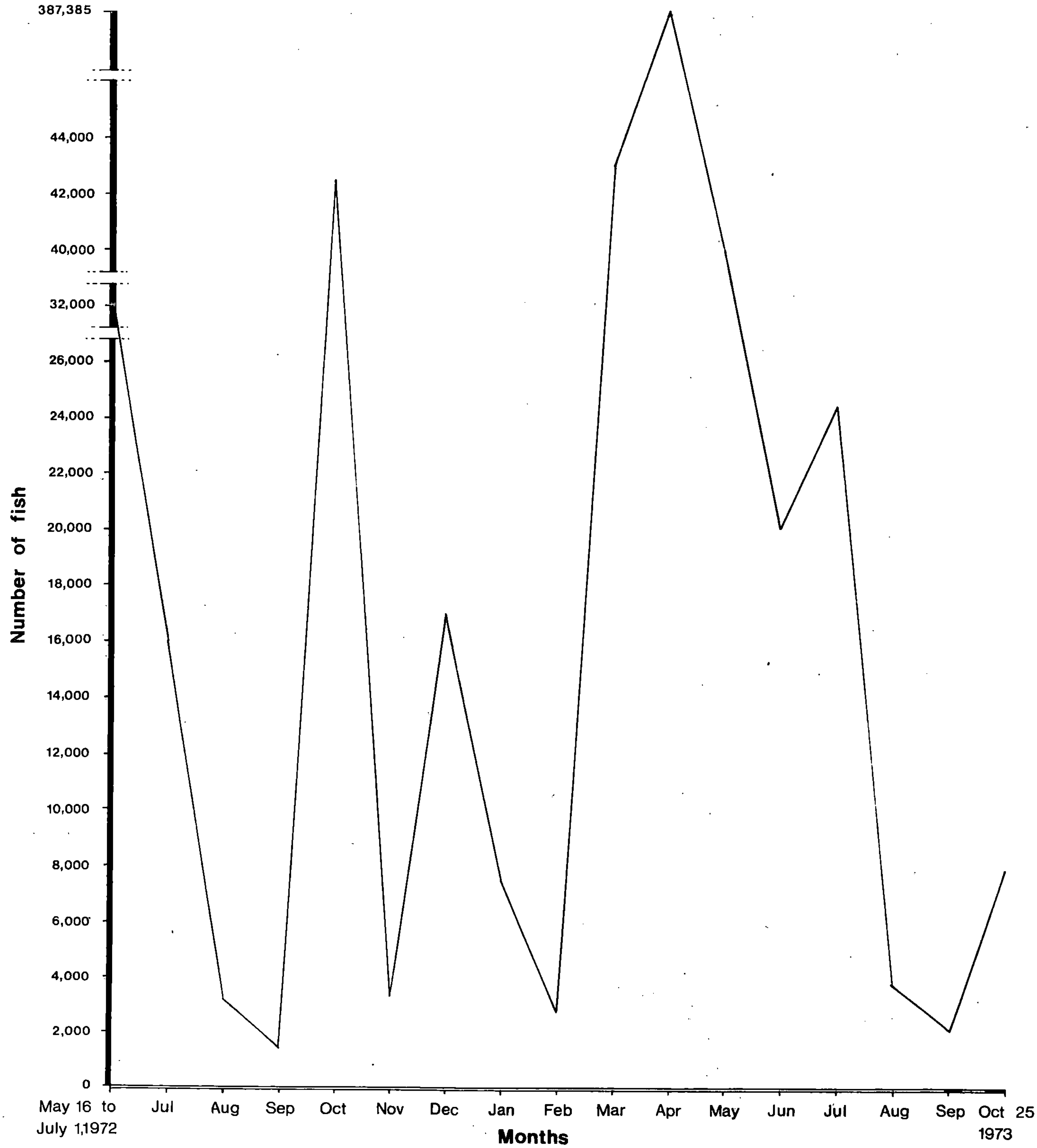


Figure D-8

Number of Pounds of Fish observed on the Traveling Screens. May 16, 1972 - October 25, 1973.

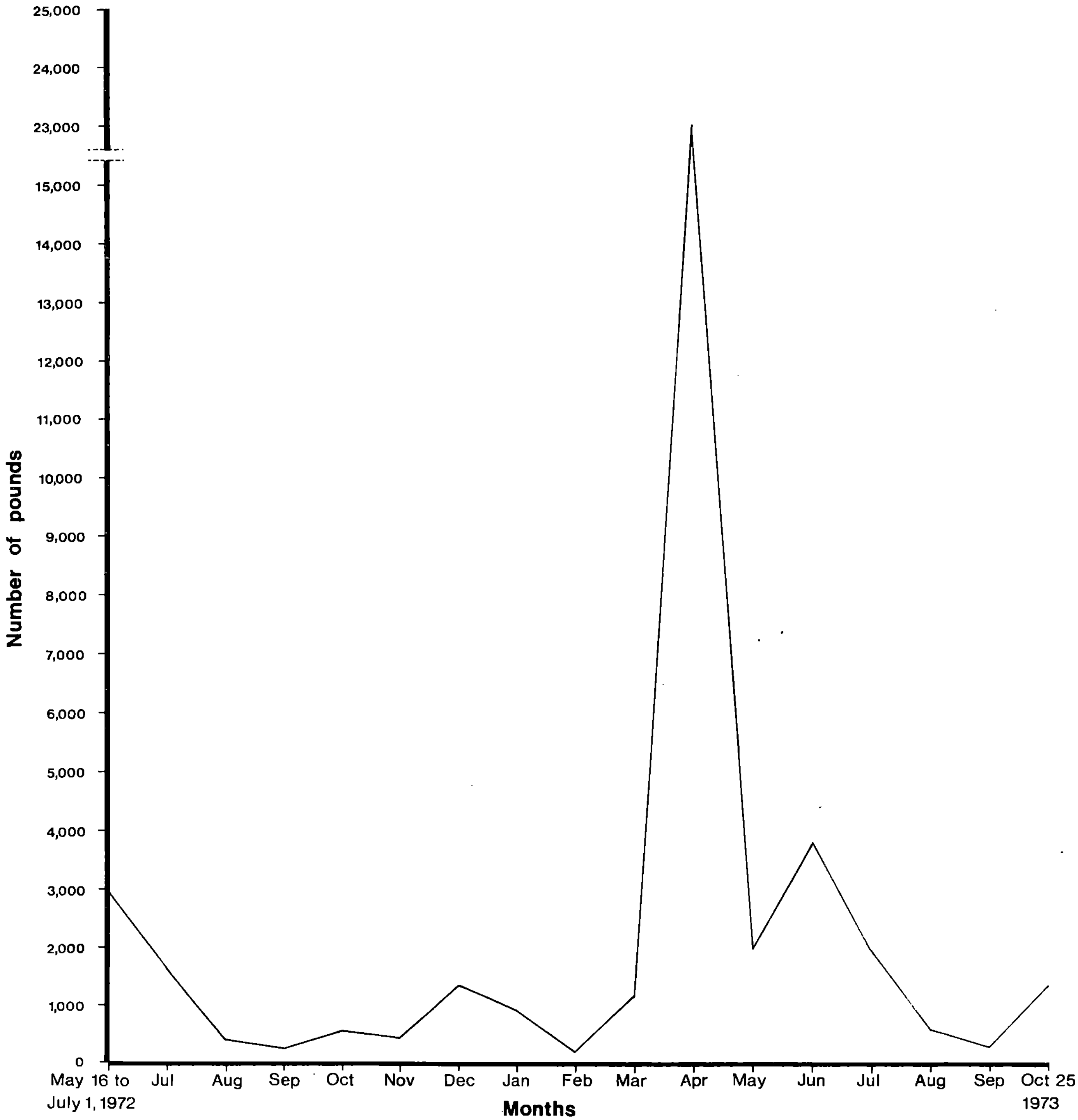


Figure D-9

Number of Alewife Observed on the Traveling Screens May 16, 1972 – October 25, 1973.

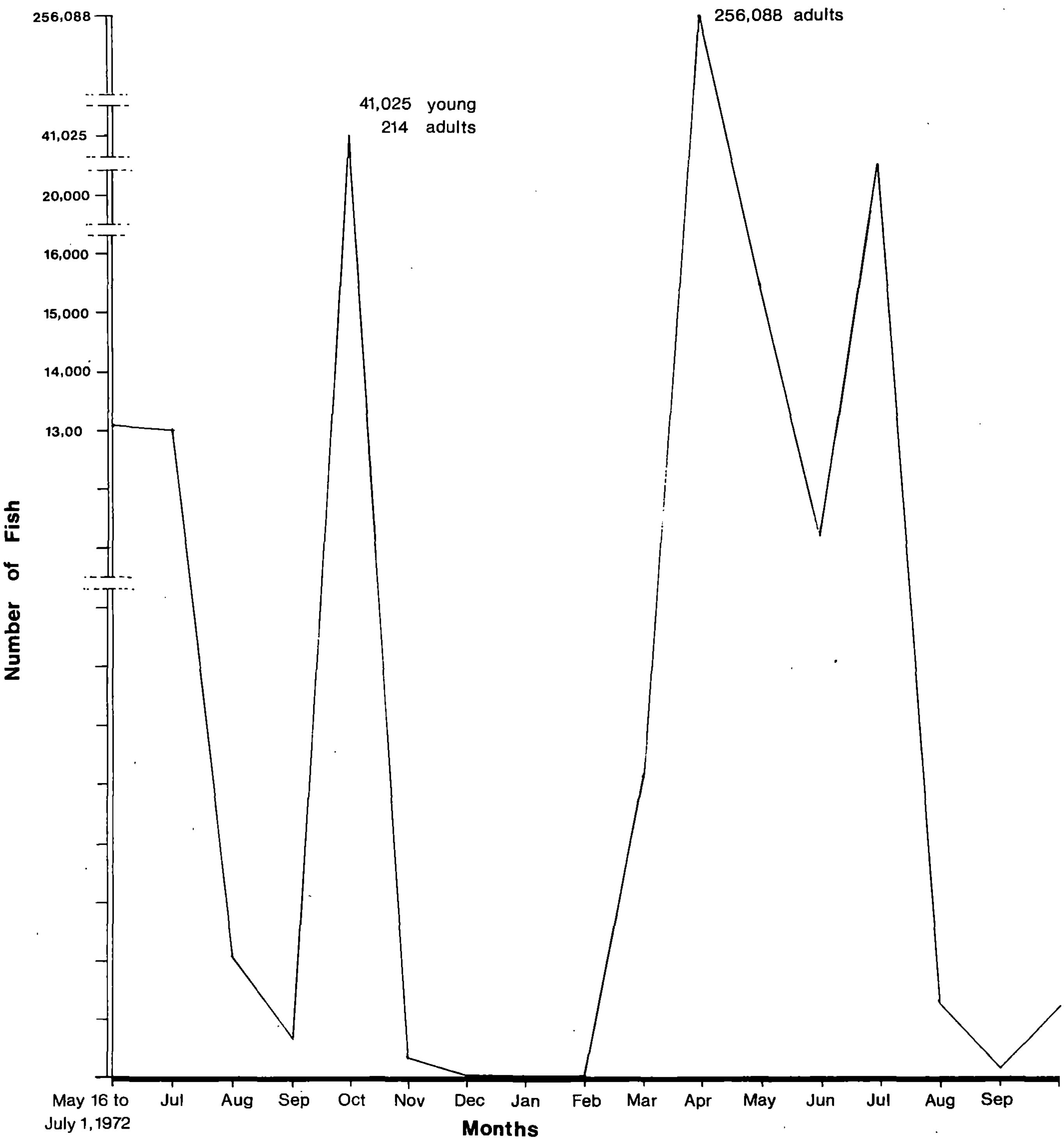


Figure D-10

Number of Perch observed on the Traveling Screens

May 16, 1972 - October 25, 1973.

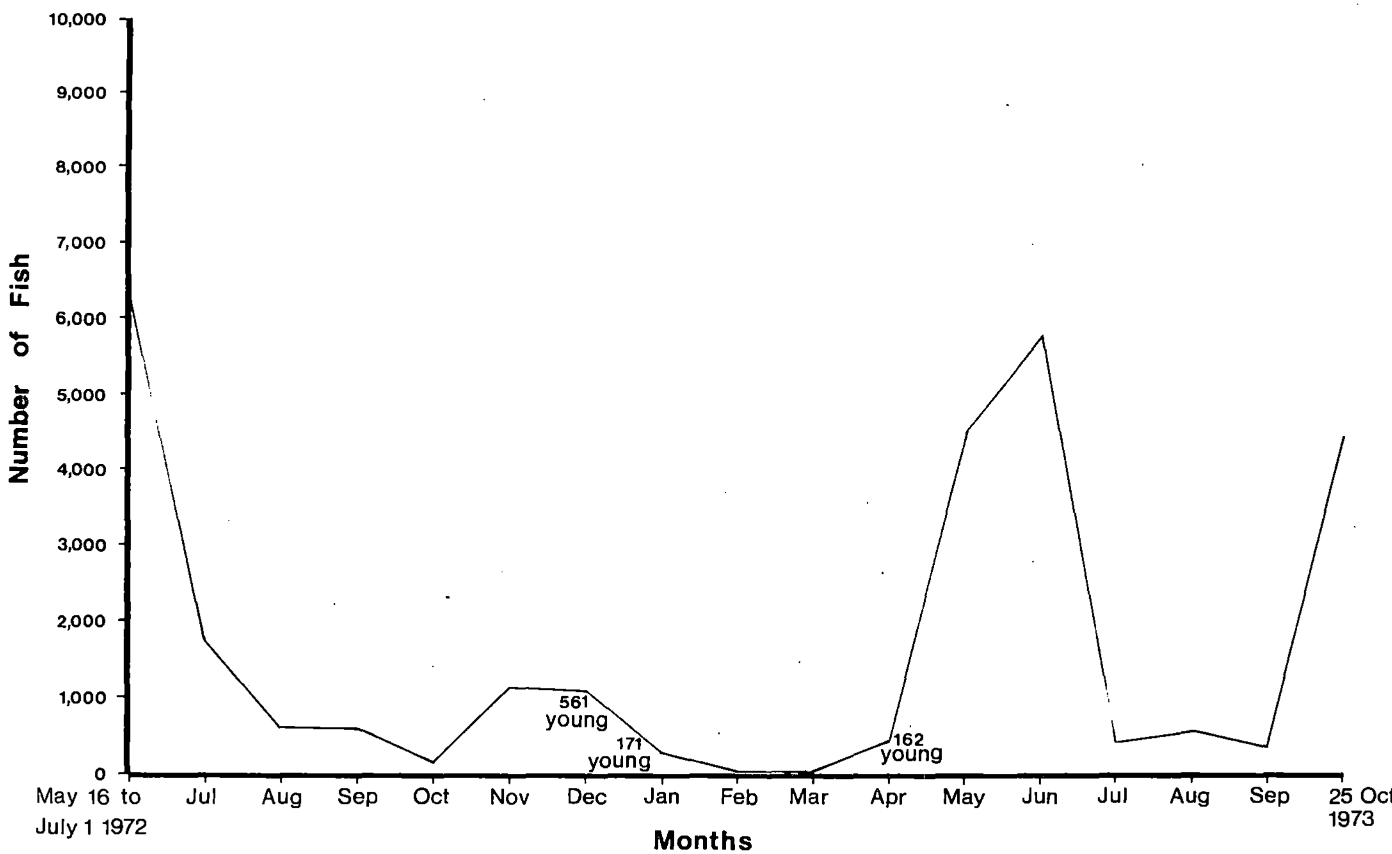


Figure D-11

Number of Spottail Shiners observed on the Traveling Screens – May 16, 1972 to Oct 25, 1973.

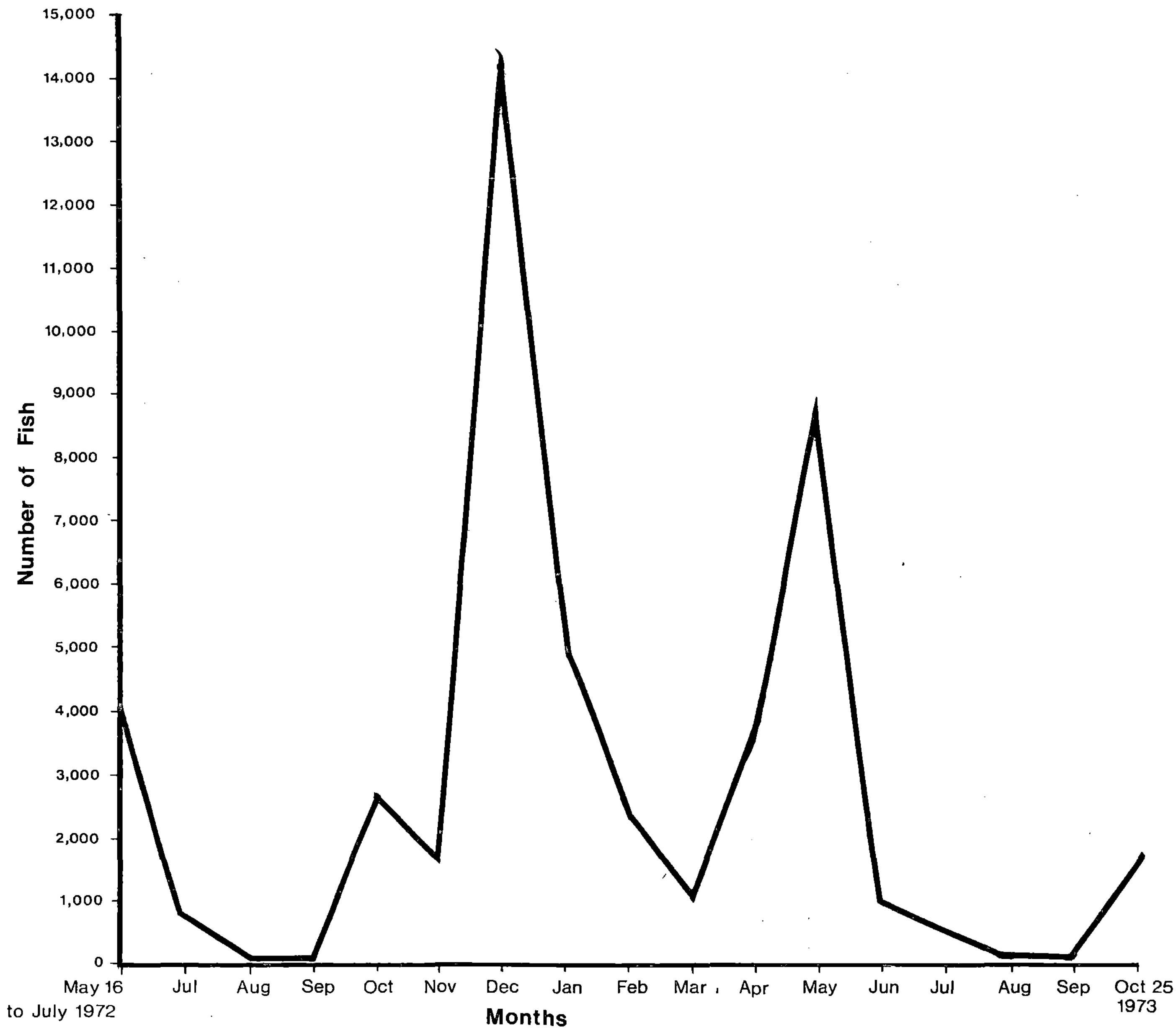
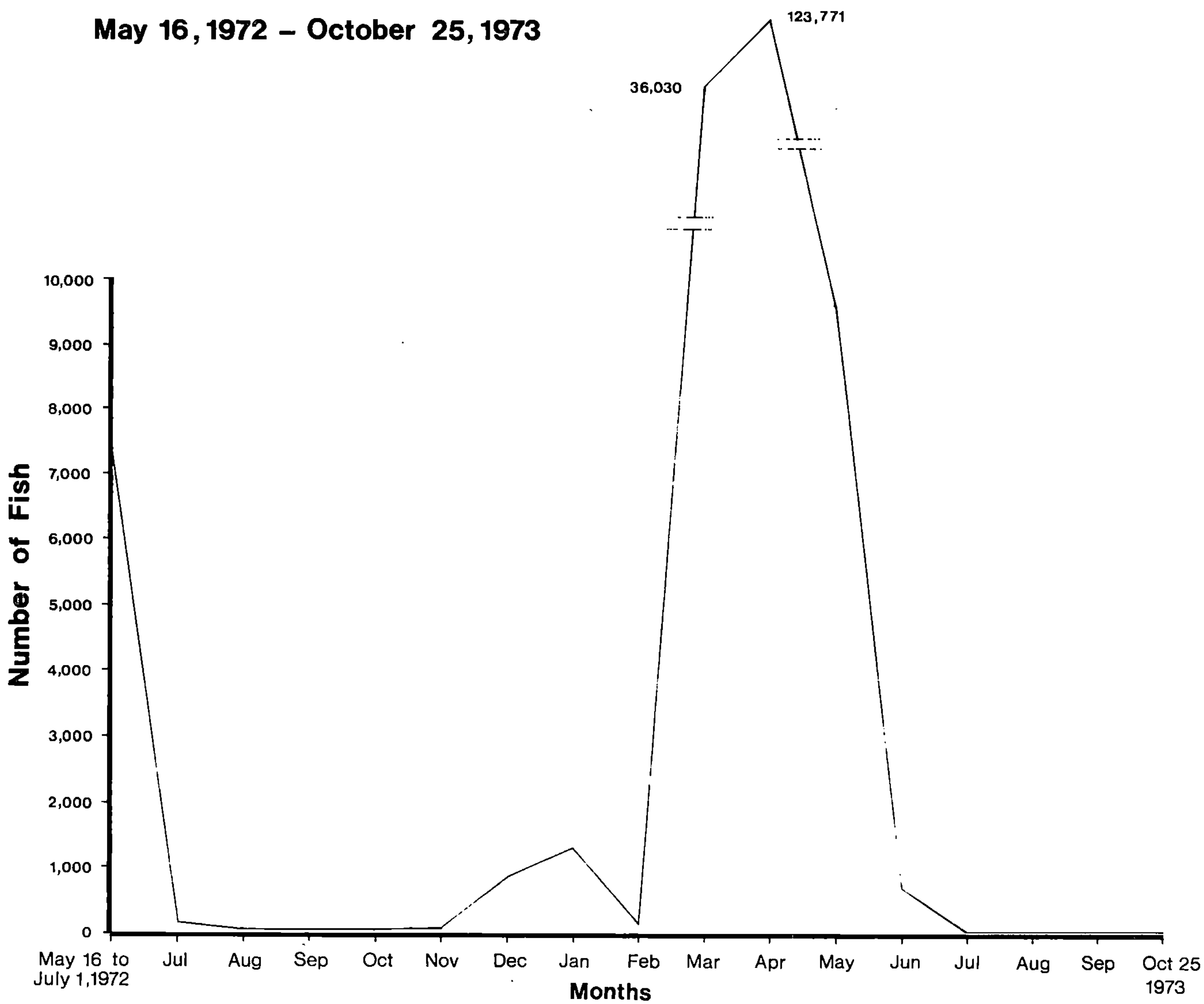


Figure D- 12

Number of Slimy Sculpin observed on the Traveling Screens.

May 16, 1972 – October 25, 1973



SECTION E

DISCUSSION ON INTERACTION OF ORGANISMS AND THE POWER PLANT IN A FOOD WEB

INTERACTION OF ORGANISMS AND THE POWER PLANT IN A FOOD WEB

The plankton, benthos and fish have been discussed in the preceding sections as discrete units. They will now be drawn together and discussed with reference to their importance in natural food webs.

The cooling water use and thermal effluent could affect the biota of the lake in various ways. The plankton are affected directly by heat and mechanical abrasion in the condenser tubes and by heat in the plume. Added heat can be either too high, decreasing productivity, or it can stimulate productivity, resulting in increases of all species or possibly changes in species composition. Increases in plankton mortality and the subsequent fallout of organic material from the plume could provide additional food for benthic organisms; bacteria, fungi and higher forms of life.

Zooplankton consume phytoplankton and smaller forms of zooplankton as food and they in turn are eaten by fish. Benthic organisms can be filter feeders or browsers, eating anything that they encounter, selective detritivores, or active predators. Some benthos burrow or build tubes and nets, which may help them trap food.

Only in the case of a sinking plume are the benthos directly affected beyond the immediate vicinity of the discharge. However, they may be influenced indirectly by the higher mortalities or production of organisms living in the surface waters.

The area of Lake Michigan which was studied included water to a depth of about 100 feet. The coldest temperature encountered at this depth during the survey period was 4.5°C. Some of the coldest temperatures were present in August 1973, when an upwelling of deeper lake water occurred in a period of a few hours and ambient temperatures became as cold as, or colder than, those of May. The natural annual temperature fluctuations are greater than those caused locally by the plume. The latter would only be critical if the upper lethal limits of resident organisms were reached, but this usually only occurs in southern warm waters where ambient temperatures are very near lethal levels for some organisms.

Fish use inshore areas for a variety of activities: migration, feeding, reproduction and rearing, all or some of these activities taking place, depending on the species present. Some fish are planktivores all their lives and some only as juveniles, progressing in their diet through benthos to various sizes of fish.

The following discusses the results of the Palisades surveys relative to the importance of the entire food web.

Lake Michigan phytoplankton in the vicinity of the Palisades Plant were found to be patchily distributed throughout the water mass. The community was dominated by diatoms, which parallel the results of other studies on the lake. The Palisades plankton studies detected no gross changes in the composition of the phytoplankton groups. Annual variations were present, but no general trend was shown.

Phytoplankton losses which could be expected to result from passage through the condensers demonstrated extreme variability. The response of the phytoplankton ranged from 76 percent gain in productivity to 89.3 percent loss. The net loss due to heat was very similar in magnitude to that caused by mechanical damage. The dead cells would not be a loss to the food web, as bacterial breakdown or direct ingestion by bottom feeders would keep the materials in circulation.

Annual variations in plankton density were also studied and showed that very large fluctuations were present over the whole survey grid both before and during power plant operations.

There are very little data on the use of algae by zooplankton, so only hypothetical estimates can be made on the effects of the power plant on the algal food supply available to zooplankton in the vicinity of the plant. Many zooplankters are detritus feeders, especially in eutrophic lakes or turbid conditions. In oligotrophic lakes, many zooplankters feed on phytoplankton, especially diatoms. Other zooplankters are omnivorous or active predators, the latter being larger forms which actively compete with larval or planktivorous adult fish.

The power plant can be considered as a somewhat inefficient size-selective predator on the lake biota in the vicinity of the intake. It could cause variable changes in the numbers of phytoplankton and zooplankton, depending on the amount of heat put out and the predominance of the larger zooplankton species, which are especially vulnerable to mechanical damage. The power plant thus competed with fish and zooplankton for plankton, and with predatory fish for the fish which are entrained as larvae or impinged on the traveling screens.

Psammolittoral fauna, the microscopic organisms inhabiting the interstitial spaces between sand grains, were studied for two years. This study was discontinued as there were no indications of a lower grade psammolittoral community developing near the plant and the shorebirds, which it was postulated would be involved in this part of the food web, were seen only occasionally during the surveys.

Perch was one of the commonest fish in the Palisades area. It is very adaptable and can utilize warm and cool habitats. In 1973, the Michigan Department of Natural Resources reported that three weeks advanced spawning occurred in about 1/3 of the population sampled in the vicinity of the plant. The thermal plume was cited as a possible cause. Fingerling perch feed on cladocerans, ostracods and chironomid larvae which, in May, were found to be less abundant than in the normal spawning period of June. The range in density per grab of the small crustaceans and midges was from 1 to 10 and 1 to 15, respectively, in May and from 1 to 25 and 1 to 50, respectively, in June. No unnaturally large decreases in population densities were observed in May for the major groups of benthic organisms which would be consumed by fingerling perch. Considering the whole of Lake Michigan (22,420 sq mi) and that the area of the lake affected by the plume in the 1972-1973 measurements averaged about 231 surface acres, this could have had only a very low impact on the perch population as a whole.

When analyzing the benthic samples, significant increases were calculated for ostracods, cladocerans and some chironomid species. The two former groups are primarily planktonic and plankton densities showed large fluctuations with no trend to larger populations. Significant decreases occurred at some stations in some of the larger invertebrate organisms such as Pontoporeia hoyi (Amphipoda) which are included in the food of first-year perch. No specific area of the sampling grid exhibited significant decreases in the population densities. These occurred only at isolated sampling stations, so there could have been no widespread effect on perch populations.

Other bottom feeding fish should not have been affected by the decreases in benthic organisms which occurred at isolated stations, such as chironomids at E/2, H-1, A-2 and 1-2, since they could have benefited from areas where some of the benthos had increased, for example, F/2, C-1, C/2 and D/2. Other fish such as salmonids are predators on fish and as the screen impingement counts show, there were large numbers of possible prey in the area. The power plant "caught" considerable numbers, thus acting as a food competitor.

Alewives feed on zooplankton and phytoplankton, especially diatoms, and the adults take benthos, mostly chironomid larvae and amphipods. There was no apparent decrease in the plankton populations, and diatoms consistently dominated the phytoplankton. As previously discussed, the benthos showed natural fluctuations, and no general decrease or increase was apparent in any specific section of the survey grid. The alewife spawn in April to May and a summer to fall maximum of young occurs in the inshore areas. At the time that these fish are growing, the density of the benthos is increasing.

Bloaters are deep water spawners, so the effects of the plume should never influence their young. Bloaters were caught inshore in depths of 35 to 40 feet in the early summer. The small crustaceans, amphipods such as Pontoporeia hoyi, which compose this fish's food, were increasing in density at this time, for example, from an average of 100 per square foot in May to 300 per square foot in June at the 30 to 50 foot stations.

Smelt spawn in rivers and on gravel shoals in lakes, and there was no evidence of spawning at Palisades. Adults eat benthos and small fish. Mysis relicta is a major food item. No changes which have occurred in the benthos and plankton should significantly affect this fish. Mysis relicta is a cool, deep water form and should not be influenced by the plume.

There were no significant changes in numbers of the dominant fish in the Palisades area, but the gillnet catches of perch were less in 1973. Numbers caught per 250 feet of net dropped from an average of 74 to 46 in 1973 while other lake surveys indicated an increase in perch populations in the area. It is a spring spawner and does very little migration in its life history, so any power plant effluents would affect the local population only.

Very little is known about the food of the spottail shiner but it seems to have a higher proportion of plankton in its diet than some other shiners. Chironomid larvae also form a large part of its diet. There are no indications that such food organisms would become so scarce as to seriously affect the minnow populations.

The longnose sucker and white sucker usually spawn in streams, so the Palisades plant could not affect hatching or early larval development. They are both bottom feeders and are not in competition with piscivorous fish.

The slimy sculpin, also a bottom feeder, with quite a wide foraging range, was abundant in the area. Although this species was frequently impinged on the intake screens, there was no indication that the plant operation was having an influence on local populations.

Other species of fish found in Lake Michigan are of little relative importance to this study. They were not abundant in the vicinity of the Palisades Plant and thus their populations in this area of Lake Michigan as a whole would not be much affected by the plume.

INTRODUCTION TO APPENDICES

The attached appendices to this "final report" of the once-through cooling operation of the Palisades Nuclear Plant serve two basic purposes. First, at the beginning of each appendix, is a reference key which identifies the sources where the basic data or original descriptions of particular surveys may be found. Where the data exist in more than one source or location, preference is given to the most recent official submittal. All data pertaining to the study are, of course, available through Consumers Power Company and/or the coinvestigators who participated in various aspects of the study.

The second purpose of each appendix is to place in the record additional data and the results of investigations which have not been included in previous submittals.

KEY TO DATA LOCATIONS - TEMPERATURE

1. Preoperational Lake Temperature Profiles Near Palisades Plant - CP Co Data File.

2. Palisades Plant Intake and Discharge and Plume Temperatures:
   Dec 31, 1971 - June 30, 1972 - Special Report #4 to AEC
   July 1, 1972 - Dec 31, 1972 - Semiannual Operations Report #4
   Jan 1, 1973 - June 30, 1973 - Semiannual Operations Report #5
   July 1, 1973 - Dec 31, 1973 - Semiannual Operations Report #6

3. Thermal Plumes by Argonne National Laboratory 1972 - "Field Investigations of Heated Discharges from Nuclear Power Plants on Lake Michigan; 1972" ANL/ES-32.

4. Lake Temperature Profiles During Operation Biological Surveys - Attached Tables A-1A Through A-7A.

5. Ice Melt Photographs - Semiannual Operations Report #5.

KEY TO DATA LOCATIONS - INTAKE CURRENTS

1. Intake Current Measurements - 8/72, 10/73 - Attached Table A-8A.

KEY TO DATA LOCATIONS - SEDIMENT ANALYSIS

1. Sediment Particle Size and Organic Carbon 10/71 - Attached Table A-9A.

2. Sediment Particle Size and Organic Carbon 10/73 - Attached Table A-10A.

Table A-1A: Temperature Profile (°C)
Lake Michigan near Palisades
19 June 1972

DEPTH (ft.)	STATION											
	A-5 10'	A-1	I-5 21'	I-5 12'	I-2 13'	I-1 10'	CS-1 70'	CS-2	CS-20'	CS-10'	B-1 24'	B-1/2
Surface	9.7	16.65	16.3	16.2	16.7	17.5	11.5	15.5	14.8	15.0	18.4	19.5
5	9.7	15.1	13.9	12.1	16.7	17.5	9.7	16.1	13.5	14.3	15.4	16.7
10	9.7	15.0	11.2	11.3	16.7	17.5	9.3	12.7	12.6	12.5	14.6	15.0
15		14.5	11.1		16.7		8.4	12.3	12.3		14.5	14.7
20			11.0				7.4	12.1	12.1		13.9	
25							6.1	11.9				
30							5.8					
35								11.6				
40							5.2					
45												
50							5.2					
55												
60							5.1					
65												
70							4.5					

DEPTH (ft.)	STATION							
	C-1	C-1/2	D-1/2	E-1/2	F-1 42'	F-1/2 26'	G-1/2 20'	H-2
Surface	17.0	16.1	17.2	16.7	17.0	17.0	19.8	14.9
5	16.1	15.0	15.0	15.0	15.6	15.6	19.7	14.9
10	14.5	15.0	15.0	15.0	14.7	14.7	19.7	14.9
15	13.9	14.7	14.7	14.7	14.5	14.7	19.7	14.7
20	12.8	14.5	14.7	14.5	13.9	14.5	19.7	14.7
25	12.0			12.8	12.8	12.8		14.7
30	11.1				11.4			14.7
35					10.3			14.7
40					10.3			14.6

Table A-1A: (continued)

DEPTH (ft.)	STATION							
	H-1 25'	H-1/2	I-5 28'	C-5	C-2	F-5	F-2	G-2
Surface	18.4	20.1	18.7	17.1	16.2	15.9	15.5	15.9
5	18.4	20.0	12.9	11.5	11.7	12.7	11.6	12.3
10	18.4	20.0	11.1	9.9	9.8	12.5	10.1	9.7
15	18.4	20.0	10.0	9.7	9.2	12.0	9.4	8.8
20	18.4		9.4	9.3	8.1	10.4	8.5	8.2
25	18.4		8.9	9.1	8.0	9.6	8.1	7.9
30				9.0	7.9	8.7	8.1	7.9
35					7.9		8.1	7.9
40				8.6	7.9	8.3	8.1	7.8
45					7.9		8.1	7.7
50				8.2	7.9	8.1	8.1	7.7
55								7.7
60				7.6		7.9		
65								
70				7.5				
75								
80				7.5		7.6		
85								
90				7.4		7.6		
95								
100								

Table A-2A: Temperature Profile ($^{\circ}C$)
Lake Michigan near Palisades
9 October 1972

DEPTH (ft.)	STATION															
	A-5	A-5 20'	A-5 10'	A-2	A-2 10'	A-1	A-1 10'	I-5	I-5 20'	I-5 10'	I-2 13'	I-1 12'	CS-1	CS-2	CS-20'	CS-10'
Surface	13.4	13.4	13.4	13.9	13.4	13.6	13.4	13.1	13.1	13.4	13.1	13.1	13.4	13.6	13.4	13.4
5	13.4		13.1	13.6	13.4	13.6	13.4	13.1	13.1	13.4	13.1	13.1	13.4	13.4	13.4	13.4
10	13.4	13.1	13.1	13.6	13.4	13.4	13.4	13.1	13.1	13.4	13.1	13.1	13.4	13.4	13.4	13.4
15	13.4			13.6		13.4		13.1	13.1		13.1		13.4	13.4	13.4	
20	13.4	12.8		13.6				13.1	13.1				13.4	13.4	13.4	
25	13.4			13.6				13.1					13.4	13.4		
30	13.4							13.1					13.4	13.4		
35	13.4												13.4	13.4		
40	13.4												13.4			
45													13.4			
50													13.4			
55													13.4			
60													13.4			
65																
70													11.1			

DEPTH (ft.)	STATION													
	CN-1*	CN-2	CN-20'	CN-* 10'	B-1	B-1/2	B-1/4	C-1	C-1/2	D-1/2	E-1/2	E-1/4	F-1	F-1/2
Surface		13.4	13.4		13.6	13.9	14.1	13.6	14.2	13.9	14.5	14.7	13.1	14.1
5		13.4	13.4		13.6	13.6	13.9	13.4	13.9	13.4	14.5	14.2	13.1	13.1
10		13.4	13.4		13.6	13.4	12.8	13.4	13.4	13.1	13.4	13.1	13.1	13.1
15		13.4	13.4		13.6	13.1		13.4	13.1	13.1	13.1	12.8	13.1	13.1
20		13.4	13.4		13.4			13.4	12.8	13.1	13.1	12.8	13.1	13.1
25		13.4						13.4		13.1	13.1		13.1	13.1
30		13.4						13.4					13.1	
35		13.4						13.4					13.1	
40													13.1	

Table A-2A: (continued)

DEPTH (ft.)	STATION									
	G-1/2	H-2 47'	H-1	H-1/2 13'	H-1/4 8'	C-5	C-2	F-5	F-2	G-2
Surface	13.1	13.1	13.1	13.1	13.1	12.8	13.6	12.5	13.1	12.8
5	13.1	13.1	13.1	13.1		12.8	13.6	12.5	13.1	12.8
10	13.1	13.1	13.1	13.1	12.8	12.8	13.6	12.5	13.1	12.8
15	13.1	13.1	13.1			12.8	13.4	12.5	13.1	12.8
20	13.1	13.1	13.1			12.8	13.4		13.1	12.8
25	13.1	13.1	13.1			12.8	13.4	12.2	13.1	12.8
30		13.1				12.8	13.4	12.2	13.1	12.8
35		13.1					13.1	12.2	12.8	12.8
40		13.1				12.5	12.8	12.2	12.8	12.8
45		13.1					12.8	12.2	12.8	12.8
50						12.2	12.8	12.2	12.8	12.8
55								12.2		12.2
60						12.0		12.2		12.2
65								12.2		
70						11.7				
75						11.1		11.7		
80						9.5		8.6		
85								8.6		
90								8.6		
95						8.9		8.6		
100										

* Not recorded

Table A-3A Temperature Profile (^{o}C)
South Haven - May, 1973

DEPTH (ft.) \ STATION	A-1	A-1 10'	A-2	A-2 10'	A-5	A-5 20'	A-5 10'	B-1	B-1/2	B-1/4	C-1/2	C-1	D-1/2
Surface	10.5	10.8	10.0	12.5	10.5	10.0	10.0	10.0	10.3	10.5	10.3	10.5	10.3
5	10.3	10.5	10.0	10.0	10.0	10.0	10.0	10.0	10.3	10.5	10.3	10.5	10.3
10	10.3	10.5	9.5	9.7	10.0	9.5	10.0	10.0	10.3	10.3	10.3	10.5	10.3
15	10.0		9.5		9.7	9.5		10.0	10.3		10.0	10.5	10.3
20			9.5		9.7	9.5		9.5			10.0	10.0	10.0
25					9.5							10.0	10.0
30					9.5							10.0	
35					9.5							9.5	
40					9.5							9.5	
45					9.2								
50													

Table A-3A (continued)

DEPTH (ft.) \ STATION	E-1/2	E-1/4	F-1/2	F-1	G-1/2	H-1/4	F-2	C-2	C-5	F-5	CS-1	CS-2	CS 20'	CS 10'
Surface	10.5	10.8	10.5	10.8	10.8	17.2	10.8	10.5	10.0	9.5	9.5	10.5	9.5	9.5
5	10.5	10.5	10.5	10.8	10.8	12.0	10.8	10.5	9.5	9.5		10.3	10.0	9.5
10	10.5	10.5	10.5	10.5	10.5	11.1	10.8	10.5	9.5	9.5	8.2	10.3	10.0	9.5
15	10.5	10.5	10.5	10.5	10.5		10.5	10.5	9.5	9.5	9.5	10.3	9.7	
20	10.3	10.5	10.3	10.5	10.5		10.8	10.3	9.5	9.5	9.5	10.0	9.7	
25	10.3		10.3	10.5			10.5	10.3	9.5	9.5	9.5	9.7		
30				10.5			10.5	10.3	9.5	9.5	9.5	9.7		
35				10.5			10.0	10.3	9.5	9.5	8.4	9.5		
40				10.3			10.0	10.0	9.5	9.5	8.4			
45							10.0	9.7	9.5	8.9	8.4			
50							10.0	9.7	9.5	8.9	8.4			
55														
60									9.5	8.9	7.8			
65														
70									9.2	8.9	7.2			
75														
80									8.9	8.4				
85														
90									8.4	7.5				
95														
100									7.8					

Table A-3A (continued)

DEPTH (ft.) \ STATION	I-5	I-5 20'	I-5 10'	I-2	I-1	H-1/2	H-1	H-2	G-2	CN-1	CN-2	CN 20'	CN 10'
Surface	9.5	10.0	10.3	10.5	11.6	11.6	10.5	11.1	10.0	10.0	10.0	10.8	11.1
5	9.5	9.7	10.3	10.5	11.6	11.6	10.5		10.0	10.0	10.0	10.8	10.5
10	9.5	9.7	10.0	10.5	11.1	11.6	10.3	10.0	10.0	10.0	10.0	10.5	10.5
15	9.5	9.5				11.1	10.0	9.5	10.0	10.0		10.3	
20	9.5	8.4					10.0	9.5	10.0	10.0	9.7	10.0	
25	8.9						10.0	9.5	9.7	9.5	9.5		
30								9.5	9.7	9.5	9.5		
35								9.5	9.5	9.2	9.5		
40								9.5	9.5	9.2			
45								9.5	9.5				
50									9.5	8.9			
55													
60									9.2	8.9			
65													
70										8.3			
75										7.5			

Table A-4A: Temperature Profile (^{o}C)
South Haven - June, 1973

STATION / DEPTH (ft.)	A-1 15'	A-1 10'	A-2 23'	A-2 10'	A-5 40'	A-5 20'	A-5 10'	B-1 24'	B-1/2 15'	B-1/4 11'	C-1/2 23'	C-1 37'	D-1/2
Surface	20.5	19.5	19.5	20.8	19.5	21.4	21.6	21.4	21.6	25.5	25.0	20.5	18.6
5	19.5	18.9	18.9	18.9	19.5	18.9	18.9	18.9	20.0	22.8	23.0	20.0	18.4
10	18.4	18.4	18.4	18.4	19.2	18.4	17.0	18.6	18.9	18.9	19.5	19.2	18.4
15	17.8		17.8		18.9	17.8		18.4	18.4		18.6	19.2	18.1
20			17.2		18.9			18.2			16.7	19.2	18.1
25			17.2		17.2			17.0			15.5	17.8	17.2
30					16.1			16.6				16.1	
35					15.3							15.3	
40					14.2								
45													

Table A-4A: (continued)

DEPTH (ft.) \ STATION	E-1/2 26'	D-1/4	F-1/2	F-1 42'	G-1/2 23'	H-1/4 8'	F-2 51'	C-2 50'	C-5 98'	F-5 95'	CS-1 70'	CS-2 35'	CS 20'	CS 10'
Surface	21.1	18.9	18.6	19.2	18.9	20.3	19.5	21.1	20.8	21.4	21.1	21.6	21.1	21.1
5	20.8	18.6	18.4	18.9	18.6	18.6	18.9	20.5	20.5	21.1	20.8	21.4	20.8	20.5
10	18.9	18.4	18.1	18.9	18.4	18.1	18.9	20.0	18.6	20.3	20.0	20.3	20.3	20.0
15	17.2	18.2	18.1	18.6	18.1		18.9	19.7				19.4	19.4	
20	16.1	17.8	17.8	18.4	17.8		18.9	19.5	17.2	19.5	17.5	19.2	18.9	
25	13.9	16.9	16.8	18.4	16.4		17.2	19.5				18.9		
30				15.8			17.2	18.9	17.2	17.2	16.5	17.8		
35				13.1			11.6	17.5				16.6		
40				10.5				15.5	16.6	16.4	15.8			
45				10.0				12.8						
50								10.8	16.1	16.1	15.3			
55											14.4			
60									15.3	15.5	13.4			
65											9.7			
70									14.5	15.0	9.7			
75									13.9	12.7				
80									7.5	11.3				
85									7.5	8.3				
90									7.5	8.1				
95									7.5	8.1				

Table A-4A (continued)

DEPTH (ft.) \ STATION	I-5 28'	I-5 20'	I-5 10'	I-2 15'	I-1 12'	H-1/2 13'	H-1 24'	H-2 47'	G-2 58'	CN-1 70'	CN-2 35'	CN 20'	CN 10'
Surface	21.6	21.1	21.5	23.4	22.2	21.1	18.4	19.4	20.0	20.0	18.9	19.2	17.8
5	21.6	20.5	20.0	20.5	20.8	19.5	17.8	18.9	19.5	19.5	18.9	18.4	17.5
10	19.5	19.5	18.4	18.9	18.4	18.4	17.8	18.9	19.5	19.5	18.6	18.1	17.2
15	18.1	17.2		17.8	18.1	17.8	17.8	18.9		19.2	18.6	18.1	
20	17.5	16.4					17.8	18.9	19.2	18.9	18.4	17.5	
25	14.7						17.2	16.6	16.6	16.1	17.8		
30	13.9							15.5	13.4	15.0	14.7		
35								12.2	12.2	14.5	12.8		
40								11.1	10.0	14.5			
45								10.0	8.9	13.1			
50								9.5	8.9	13.1			
55									8.9				
60										8.9			
65													
70										8.4			
75													

Table A-5A: Temperature Profile (^{o}C)
South Haven - August, 1973

STATION / DEPTH (ft.)	A-1 15'	A-1 10'	A-2 23'	A-2 10'	A-5 40'	A-5 20'	A-5 10'	B-1 24'	B-1/2	B-1/4	C-1/2 23'	C-1 37'	D-1/2 25'
Surface	8.9	8.9	8.9	9.5	11.6	12.2	9.2	8.9	8.9	10.5	11.7	11.1	11.1
5	8.4	8.4	8.9	8.4	10.6	8.9	8.9	8.4	7.8	7.8	11.1	11.1	11.1
10	8.4	8.4	8.4	8.4	8.4	8.4	8.9	7.8	7.8	7.8	8.4	8.9	8.4
15	7.8		8.4		8.4	8.4		7.8	7.2		7.8	7.8	8.4
20			8.4		7.8	8.4		7.8			7.8	7.8	8.4
25			7.8		7.8			7.8			7.8	7.8	7.8
30					7.8							7.8	
35					7.8							7.8	
40					7.8								
45													

Table A-5A: (continued)

DEPTH (ft.) \ STATION	E-1/2 26'	E-1/4	F-1/2 26'	F-1 42'	G-1/2 23'	H-1/4 8'	F-2 51'	C-2 50'	C-5 98'	F-5 95'	CS-1 70'	CS-2 35'	CS 20'	CS 10'
Surface	10.5	10.0	11.1	11.1	9.4	8.4	11.1	8.9	13.9	13.4	15.0	10.0	10.6	10.6
5	7.8	8.4	11.1	11.1	8.9	7.8	11.1	8.9	13.9	13.4	15.0	9.5	10.0	9.5
10	7.8	7.8	10.0	8.4	8.4	7.8	9.5	8.4	13.9	13.4	14.4	8.9	8.9	8.9
15	7.5	7.8	8.4	7.8	7.8		7.8	8.4	13.4	12.8	14.4	8.4	8.9	
20	7.5	7.5	7.8	7.8	7.8		7.8	8.4	11.1	11.1	13.9	8.4		
25	7.5		7.8	7.8	7.8		7.8	7.8		8.4	12.8	8.4		
30				7.8			7.2	7.8	9.5	6.7	12.2	8.4		
35				7.8			7.2	7.8	7.8	6.1	7.8	8.4		
40				7.8			7.2	7.8	7.2	6.1	7.2			
45							7.2	7.8	6.1	5.5	7.2			
50							7.2	7.2	6.1	5.5	7.2			
55														
60									5.0	5.5	7.2			
65														
70									5.0	5.5	7.2			
75														
80									5.0	5.5				
85														
90									5.0	5.5				
95														
100										5.5				

Table A-5A: (continued)

DEPTH (ft.) \ STATION	I-5 28'	I-5 20'	I-5 10'	I-2 13'	I-1 12'1	H-1/2 13'	H-1 24'	H-2 47'	G-2 58'	CN-1 70'	CN-2 35'	CN 20'	CN 10'
Surface	10.0	10.0	8.9	9.4	10.0	10.0	10.5	10.0	11.7	12.2	11.7	8.9	8.9
5	8.9	8.4	8.4	8.4	7.8	7.8	8.4	8.9	11.7	12.2	11.1	8.9	8.9
10	8.4	7.8	8.4	7.8	7.8	7.8	7.8	8.9	11.1	11.6	8.4	8.4	8.9
15	7.8	7.8		7.8	7.2	7.8	7.8	8.4	7.8	11.1	8.4	8.4	
20	7.8	7.8					7.8	7.8	7.2	10.5	8.4	8.4	
25	7.8						7.8	7.8	7.2	7.8	8.4		
30	7.8							7.8	7.2	6.2	8.4		
35								7.2	7.2	5.6	8.4		
40								7.2	7.2	5.6			
45								7.2	6.6	5.6			
50									6.6	5.6			
55									6.6	5.6			
60										5.6			
65													
70										5.6			
75													

Table A-6A: Temperature Profile (^{o}C)
South Haven - October, 1973

STATION / DEPTH (ft.)	A-1 15'	A-1 10'	A-2 23'	A-2 10'	A-5 40'	A-5 20'	A-5 10'	B-1 24'	B-1/2 15'	B-1/4 11'	C-1/2 23'	C-1 37'
Surface	14.5	14.5	14.25	14.5	14.2	14.5	14.5	14.5	14.75	15.0	15.0	15.0
5	14.25	14.25	14.25	14.5	14.2	14.5	14.5	14.5	14.5	14.75	15.0	14.75
10	14.25	14.25	14.1	14.25	14.2	14.5	14.5	14.25	14.25	14.75	14.75	14.5
15	14.25		14.0		14.2	14.5		14.25	14.25		14.75	14.5
20			14.0		14.2	14.5		14.0			14.5	14.5
25					14.2						14.5	14.25
30					14.2							14.25
35					14.2							14.25
40.					14.2							
45												

Table A-6A (continued)

STATION / DEPTH (ft.)	D-1/2 25'	E-1/2 26'	E-1/4 20'	F-1/2 26'	F-1 42'	G-1/2 23'	H-1/4 8'	F-2 51'	C-2 50'	C-5 98'	F-5 95'	1-5 28'	1-5 20'	1-5 10'
Surface	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.0	15.0	15.25	15.25	15.5
5	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0			15.25	15.25	15.25
10	14.5	14.5	14.5	14.5	14.75	14.75	14.75	14.5	14.5	13.5	14.0	14.8	15.0	15.0
15	14.5	14.5	14.5	14.5	14.75	14.5		14.5	14.5			14.75	14.75	
20	14.5	14.5	14.25	14.25	14.75	14.5		14.25	14.25	13.25	14.0	14.75	14.75	
25	14.25	14.5		14.25	14.75	14.5		14.25	14.25			14.75		
30					14.25			14.25	14.25	13.0	13.8	14.50		
35					14.25			14.25	14.25	12.5	13.75			
40					14.25			14.25	14.25	12.5	13.75			
45								14.25	14.25					
50								14.0	14.25	12.0	13.0			
55														
60										11.0	12.0			
65														
70										9.0	9.5			
75														
80										7.5	7.5			
85														
90										7.0	7.5			
95										7.0	7.5			
100														

Table A-6A: (continued)

STATION / DEPTH (ft.)	I-2 15'	I-1 12'	H-1/2 13'	H-1 24'	H-2 47'	G-2 58'	CN-1 70'	CN-2 35'	CN 20'	CN 10'
Surface	15.2	15.5	15.0	15.2	15.0	14.75	13.6	14.5	14.5	14.2
5	15.0	15.0	15.0	15.0	15.0	14.75	13.6	14.5	14.5	14.2
10	15.0	14.9	14.75	14.9	14.5	14.5	13.6	14.5	14.5	14.2
15	14.75	14.75	14.50	14.5	14.5	14.5	13.6	14.2	14.5	
20				14.25	14.25	14.25	13.6	14.2	14.5	
25				14.25	14.25	14.25	13.6	14.2		
30					14.25	14.25	13.6	14.2		
35										
40					14.25	14.25	13.4			
45										
50						14.0	13.4			
55										
60						14.0	12.8			
65										
70							11.7			

Table A-7A: Temperature profile (^{o}C)
Lake Michigan near Palisades
June 1974

DEPTH (ft.)	STATION A-2	A-5	B-1	C-1/2	C-1	D-1/2	F-1/2	F-1	G-1/2	CS2	I-5	H-1	H-2	CN2
Surface	15.3	15.0	17.0	15.0	15.0	17.0	16.5	16.5	16.0	16.5	17.0	16.5	16.0	14.7
5	15.3	15.0	17.0	15.0	15.0	17.0	16.5	16.5	16.0	16.5	17.0	16.5	16.0	14.7
10	15.3	15.0	17.0	15.0	15.0	17.0	16.5	16.5	16.0	16.5	17.0	16.5	16.0	14.7
15	15.3	15.0	17.0	15.0	15.0	17.0	16.5	16.5	16.0	16.5	17.0	16.5	16.0	14.7
20	15.0	15.0	17.0	15.0	15.0	17.0	16.5	16.5	16.0	16.5	17.0	16.5	16.0	14.7
25	15.0	15.0	17.0	15.0	15.0	17.0	16.5	16.5	16.0	16.5	17.0	16.5	16.0	14.5
30		15.0			14.7			16.5		16.5	17.0		16.0	14.5
35		15.0			14.7			16.5		16.5			16.0	14.5
40		15.0			15.0			16.5					16.0	
45													16.0	

Table A-8A Results of current measurements made at the Palisades nuclear power plant intake crib:

August 15, 1972

Station	Time	Location	Current Speed (ft./sec.)
1	1420	North side	.75
2	1427	East side	.79
3	1433	South side	.75
4	1437	West side	.82

October 14, 1973

Station	Time	Location	Current Speed (ft./sec.)
1	1330	North side	.95
2	1338	East side	.75
3	1345	South side	.69
4	1354	West side	.71

Table A-9A: % sample, substrate particle size (m.m.) and % organic carbon, south Haven - October 1971

SUBSTRATE PARTICLE SIZE:		>4.76	>1.4	>0.707	>0.297	>0.149	>0.074	<0.074	% ORGANIC CARBON
MESH SIZE:		4	14	25	50	100	200	Passing 200	
STATION	DEPTH ZONE								
A-1	0 - 20 feet	0.0	1.8	2.8	26.0	62.5	6.1	0.8	1.07
B-1/2		0.0	0.6	1.7	9.1	57.5	28.0	3.0	0.33
H-1/2		0.0	0.4	2.1	13.0	66.5	17.7	0.3	0.15
I-1		0.0	0.3	5.6	23.7	54.8	13.8	1.8	0.42
I-2		0.0	0.0	0.1	7.6	89.8	2.1	0.4	3.30
									$\bar{x}$ 1.054
CN-2	21 - 40 feet	1.4	3.2	2.2	30.5	54.8	7.7	1.4	0.95
CS-2		0.0	0.2	0.4	3.4	69.5	25.8	0.8	0.37
A-2		0.0	1.6	6.1	27.7	47.6	15.1	1.8	0.38
A-5		0.0	0.3	3.1	22.8	62.8	10.2	0.8	1.37
B-1		0.0	0.3	3.1	24.5	66.6	5.2	0.3	4.24
C-1/2		0.0	0.2	2.5	33.2	57.6	5.9	0.6	0.49
C-1		0.0	0.1	1.9	9.9	47.5	40.3	0.3	0.38
D-1/2		0.0	0.4	1.3	29.7	58.2	9.4	0.9	0.25
E-1/2		0.0	0.0	2.4	33.0	58.0	5.4	1.2	1.11
F-1/2		0.0	0.2	0.6	11.6	60.0	26.1	1.5	0.0
G-1/2		0.0	3.2	7.0	26.1	58.8	4.3	0.6	2.65
H-1		0.0	0.7	1.6	4.9	72.6	20.0	0.2	0.17
I-5		0.0	0.6	1.5	9.1	66.8	19.9	2.1	0.24
									$\bar{x}$ 1.054
C-2	41 - 60 feet	0.0	0.0	2.2	27.2	46.0	20.5	4.1	6.82
F-1		0.0	0.0	2.5	19.1	62.3	15.3	0.8	2.03
F-2		0.0	0.3	1.7	24.0	64.0	9.3	0.8	2.58
G-2		0.0	0.0	0.5	20.0	69.6	7.8	2.1	6.31
H-2		0.0	0.8	1.2	7.2	75.0	13.5	2.2	0.51
									$\bar{x}$ 3.65
CN-1	Over 60 feet	0.0	0.3	8.6	37.5	45.2	7.8	0.6	0.04
CS-1		0.0	0.2	0.9	5.1	53.8	39.7	0.3	0.63
C-5		0.0	0.5	3.1	33.5	55.1	7.4	0.4	1.21
F-5		0.0	0.2	1.0	10.1	45.9	42.5	0.2	3.27
									$\bar{x}$ 1.288

Table A-10A: % sample, substrate particle size (m.m.) and % organic carbon, South Haven - October 1973

SUBSTRATE PARTICLE SIZE:		>4.76	>1.4	>0.707	>0.297	>0.149	>0.074	<0.074	% ORGANIC CARBON
MESH SIZE:		4	14	25	50	100	200	Passing 200	
STATION	DEPTH ZONE								
A-1	0-20	0.0	<0.01	0.08	1.83	88.92	7.44	1.72	0.24
B-1/2	feet	0.0	<0.01	0.42	5.8	83.15	9.87	0.76	0.17
H-1/2		0.0	0.37	1.08	13.48	79.76	5.11	0.20	0.14
I-1		0.0	0.01	0.13	9.74	85.60	4.38	0.14	0.14
I-2		0.0	0.04	0.16	15.53	81.58	2.34	0.35	0.13
	Mean								0.16
CN-2	21-40	0.0	0.03	0.11	5.56	37.03	56.60	0.77	0.30
CS-2	feet	0.0	0.28	0.98	9.59	55.96	28.11	5.08	1.01
A-2		0.0	<0.01	0.09	0.62	68.39	29.32	1.57	0.29
A-5		0.0	0.16	0.29	25.85	50.38	22.67	0.65	0.23
B-1		0.0	0.33	0.73	1.21	70.06	26.29	1.38	0.34
C-1/2		0.0	0.05	0.17	1.29	52.16	45.67	0.66	0.28
C-1		0.0	0.01	0.31	6.41	26.98	64.98	1.31	0.37
D-1/2		0.0	0.01	0.08	1.09	46.46	51.33	1.03	0.32
E-1/2		0.0	0.50	0.32	2.01	48.48	47.31	1.38	0.37
F-1/2		0.0	0.07	0.06	0.89	55.39	42.33	1.26	0.34
G-1/2		0.0	0.02	0.10	0.59	68.86	29.57	0.86	0.22
H-1		0.0	0.25	0.09	1.23	55.32	42.29	0.82	0.42
I-5		0.0	0.17	0.05	1.05	64.08	33.40	1.25	0.37
	Mean								0.37
C-2	41-60	0.0	0.06	0.40	17.23	66.95	14.52	0.84	0.23
F-1	feet	0.0	0.10	0.50	11.26	49.36	37.31	1.47	0.43
F-2		0.0	0.08	0.25	8.99	46.15	41.68	2.85	0.59
G-2		0.0	0.02	0.06	5.89	68.26	24.55	1.22	0.48
H-2		0.0	0.09	0.09	6.71	56.73	34.47	1.91	0.59
	Mean								0.46
CN-1	Over 60	0.0	0.03	0.12	6.21	60.84	29.99	2.81	0.96
CS-1	feet	0.90	16.92	27.88	26.10	21.69	5.88	0.63	0.37
C-5		0.0	0.0	0.17	7.02	11.90	58.07	22.84	2.08
F-5		0.0	0.08	0.25	5.41	8.67	57.29	28.30	2.56
	Mean								1.49

KEY TO DATA LOCATIONS - PLANKTON

1. Plankton Volumes 1968-1970 - Sepcial Report #4 to AEC, App A.
2. Plankton Volumes 1971 - Special Report #4 to AEC, App D.
3. Plankton Volumes and Identification 1972 - Semiannual Operations Report #5, App B.
4. Plankton Volumes and Identification 1973 - Semiannual Operations Report #6, App A.
5. Plankton Volumes and Identification 1974 - Attached Tables B-1A - B-3A.
6. Plankton Entrainment Mortality: 1972 - Semiannual Operations Report #4
1/73-6/73 - Semiannual Operations Report #5
7/13-10/73 - Semiannual Operations Rept #6
7. Plankton Concentration Control Chart Comparisons - Attached Figures B1A-B19A.

KEY TO DATA LOCATIONS - ATTACHED FILAMENTOUS ALGAE & ROOTED AQUATICS

1. Periphyton Analyses 1968 & 1969 - Supplement to ER - App B.
2. Periphyton Analyses 1970 - Special Report #4 to AEC, App A.
3. Periphyton Analyses 1971 - Special Report #4 to AEC, App D.
4. Scuba Diving Surveys: 1972 - Semiannual Operations Report #4
1973 - Semiannual Operations Report #6

KEY TO DATA LOCATIONS - PSAMMOLITTORAL ORGANISMS

1. Psammolittoral Analyses 1972-73 - Semiannual Operations Report #6, App B.

1974 SURVEY - PLANKTON

Packed Cell Volumes

The packed cell volumes of plankton were measured at several stations in June and August and the results are shown in Table B-1A. The volumes were higher in June 1974 than at any time since June 1970. Sampling for plankton in October was prevented by bad weather and rough lake conditions.

Zooplankton

Results of the detailed identification and enumeration of zooplankton sampled in June 1974 are given in Table B-2A. The zooplankton standing crop was dominated numerically be *Keratella cochlearis* and *Polyarthra* spp, *Kellicottia* spp and *Keratella quadrata* were also common. The cladoceran fraction was dominated by *Bosmina* spp. The zooplankton were at a much greater density in June 1974 than in June 1973 or June 1972.

Phytoplankton

Results of the detailed identification and enumeration of phytoplankton taken on 12 and 13 June 1974 are shown in Table B-3A. The phytoplankton standing crop was again dominated by the diatoms as expected. *Synedra* and *Melosira* were dominant, with *Tabellaria*, *Asterionella* and *Fragilaria* occurring commonly.

The chrysophyte, *Dinobryon* was also present at relatively high densities. *Oscillatoria* was observed in most of the samples. The total standing crop of phytoplankton was greater in June 1974 than at any time since counting began in 1972. This high standing crop corresponded with a high packed cell volume.

Table B-1A Plankton packed cell volume 1974
(mℓ plankton per 80 ℓ lake water)

		June	August
Date:		12 - 13	12 - 14
Weather:		sunny to thick overcast	
Lake Conditions:		2-4 ft. waves	
Station:	A-2	0.55	0.15
	A-5	0.35	0.50
	B-1	0.50	0.15
	C/2	0.45	0.20
	C-1	0.10	0.30
	D/2	1.10	0.15
	F/2	0.60	0.15
	F-1	0.70	0.20
	G/2	0.40	0.15
	H-1	2.30	0.15
	H-2	0.60	0.20
	I-5	2.00	0.25
	CN2	0.40	0.45
	CS2	0.40	0.20

Table B-2A: Detailed identification - zooplankton no. /liter lake water, June, 1974

STATION	CN-2	A-2	A-5	B-1	C/2
PROTISTA					
Difflugia sp.		7.5	13	p[2]	p[3]
ROTIFERA					
Asplanchna sp.	4.7				
Keratella cochlearis	290	280	590	638	113
K. quadrata	33	17	13	66	25
Kellicottia sp.	75	43	104	192	71
Polyarthra sp.	225	160	79	258	125
Lepadella sp.					3.8
Synchaeta sp.	14		13	28	
CLADOCERA					
Bosmina	4.7		13	47	13
COPEPODA					
Nauplius	14		7.5	33	16
Cyclopoid copepod	24		16	4.7	8.4
Calanoid copepod			p[1]		
Eggs*	100	130	250	338	125
TOTAL NUMBER OF ZOOPLANKTON	780	640	1100	1600	500

* Rotifera, Crustacea
- no fish eggs observed in plankton

p[1] - present but less than 13/litre
p[2] - present but less than 9.3/litre
p[3] - present but less than 13/litre

Table B-2A: (continued)

STATION	C-1	D/2	F/2	F-1	G/2
PROTISTA					
Difflugia sp.		94			
ROTIFERA					
Keratella cochlearis	17	1200	520	480	280
K. quadrata	1.9	75	120	94	75
Kellicottia sp.	4.2	480	240	270	200
Ploesoma sp.		9.4			
Polyarthra sp.	6.3	380	280	380	280
Synchaeta sp.		38	50	25	14
Trichocerca sp.				6.3	
Filinia sp.		9.4			
CLADOCERA					
Bosmina		19	31	56	52
Chydorus					4.7
COPEPODA					
Nauplius		38	69	56	28
Cyclopoid copepod		9.4	19	25	4.7
Calanoid copepod		9.4			
Eggs *	13	540	250	230	200
TOTAL NUMBER OF ZOOPLANKTON	42	2900	1600	1600	1100

* Rotifera, Crustacea
- no fish eggs observed in plankton

Table B-2A: (continued)

STATION	H-1	H-2	I-5	CS-2
PROTISTA				
Difflugia sp.				3.1
ROTIFERA				
Asplanchna sp.				3.1
Conochilus sp.	6.2	6.3		3.1
Keratella cochlearis	580	770	460	660
K. quadrata	88	50	63	13
Kellicottia sp.	160	190	150	94
Ploesoma sp.				p[4]
Polyarthra sp.	360	430	130	150
Synchaeta sp.	13	50		59
Rotifera indet.			8.4	3.1
CLADOCERA				
Bosmina	6.2		25	16
COPEPODA				
Nauplius	43	44	21	38
Cyclopoid copepod		19	8.4	6.3
Eggs *	160	330	380	330
TOTAL NUMBER OF ZOOPLANKTON	1400	1900	1200	1400

* Rotifera, Crustacea
 - no fish eggs observed in plankton

p[4] - present but less than 6.3/litre

Table B-3A Detailed identification - net phytoplankton
no. cells/liter lake water - June 1974

STATION	CN-2	A-2	A-5	B-1	C/2
PYRRHOPHYTA					
Ceratium hirundinella	p[1]	p[2]	p[3]	p[4]	690
Pyrrhophyta indet.		p		520	p[5]
BACILLARIOPHYCEAE					
Tabellaria sp.	600	1,400	690	1,000	1,400
Asterionella sp.	6,800	2,800	4,900	5,700	2,800
Synedra sp.	27,000	45,000	31,000	30,000	30,000
Fragilaria sp.	5,800	7,000	4,900	12,000	4,900
Melosira sp.	30,000	77,000	11,000	42,000	45,000
Rhizosolenia sp.	3,200		4,200	1,000	
Surirella sp.	p	p	p		p
Gyrosigma sp.		p		p	p
Centrales indet.	18,000	39,000	2,800	6,800	37,000
Pennales indet.	5,200	p	14,000	5,800	1,400
CHLOROPHYTA					
Scenedesmus sp.	p	p			p
Pediastrum sp.	p	p	p	520	p
Spirogyra sp.	p	p	p	520	p
Staurastrum sp.	p			p	
Actinastrum sp.		1,400			p
Cosmarium sp.					690
Closterium sp.	p				p
Mougeotia sp.	1,000	p		1,600	1,400
Filaments indet.				p	p
CHRYSOPHYTA					
Dinobryon sp.	1,600	p	4,200	5,200	1,400
Mallomonas sp.	520				

Table B-3A (continued)

STATION	CN-2	A-2	A-5	B-1	C/2
CYANOPHYTA					
Agmenellum sp.				p	
Anabaena sp.	p	p	p	p	p
Chroococcus sp.	p	p	p	520	p
Coelosphaerium sp.			p		
Gomphosphaeria sp.	p	p	p	p	p
Oscillatoria sp.	2,600	4,200	2,100	1,600	2,800
TOTAL NUMBER OF ORGANISMS	100,000	180,000	80,000*	110,000	130,000

p^1 - present but less than 520/1
p^2 - present but less than 1,400/1
p^3 - present but less than 690/1
p^4 - present but less than 520/1
p^5 - present but less than 690/1

* an underestimate because of clumping of organisms.
Centrales, indet. include Cyclotella and Stephanodiscus

Pennales indet. include Diatoma and Navicula

Table B-3A (continued)

STATION	C-1**	D/2	F/2	F-1	G/2
PYRRHOPHYTA					
Ceratium hirundinella		1,000	p[8]		p[10]
Pyrrhophyta indet.	p[6]	p[7]			
BACILLARIOPHYCEAE					
Tabellaria sp.	350	2,100	690	2,800	3,700
Asterionella sp.	350	7,400	9,100	6,300	3,700
Synedra sp.	2,800	100,000	58,000	45,000	34,000
Fragilaria sp.	p	20,000	3,500	4,200	6,800
Melosira sp.	2,800	120,000	44,000	52,000	32,000
Rhizosolenia sp.		1,000		1,400	
Surirella sp.		1,000		p[9]	
Amphiprora sp.		1,000			
Centrales indet.	690	59,000	4,200	2,100	2,100
Pennales indet.	2,100	3,100	1,400	690	4,200
CHLOROPHYTA					
Scenedesmus sp.	p	1,000	690	p	p
Pediastrum sp.	p	3,100	p	p	p
Spirogyra sp.		1,000	2,800	p	p
Staurastrum sp.					p
Cosmarium sp.					p
Closterium sp.			p		p
Sphaerocystis Schroeteri					p
Mougeotia sp.	p	9,400	2,100	2,800	1,000
CHRYSOPHYTA					
Dinobryon sp.	350	21,000	4,200	3,500	2,600

Table B-3A (continued)

STATION	C-1**	D/2	F/2	F-1	G/2
CYANOPHYTA					
Anabaena sp.		p	p	p	
Chroococcus sp.		p			
Gomphosphaeria sp.	690	p		p	
Oscillatoria sp.		7,400	2,100	2,100	2,100
Microcystis sp.	p				
TOTAL NUMBER OF ORGANISMS	10,000	360,000	130,000	120,000	92,000

** Extremely dense population of very small coccoid cells, probably yeast, present.

p^{6} - present but less than 350/1

p^{7} - present but less than 1,000/1

p^{8} - present but less than 690/1

p^{9} - present but less than 690/1

p^{10} - present but less than 520/1

Table B-3A (continued)

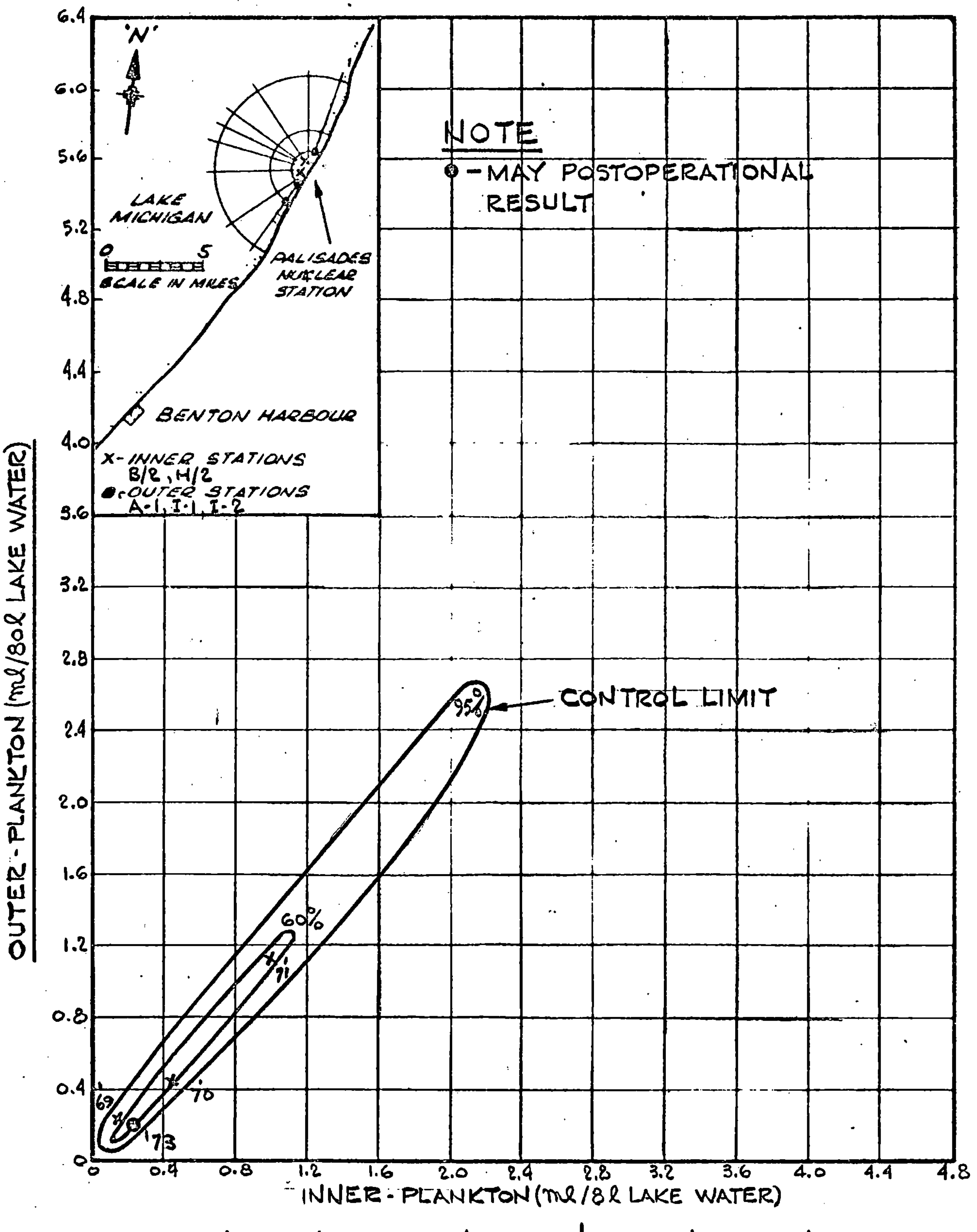
STATION	H-1**	H-2	I-5**	CS-2
PYRRHOPHYTA				
Ceratium hirundinella		p[12]		p[14]
Pyrrhophyta indet.		p	p[13]	
BACILLARIOPHYCEAE				
Tabellaria sp.	1,000	4,900	4,200	1,000
Asterionella sp.	9,000	11,000	6,300	4,500
Synedra sp.	65,000	53,000	32,000	11,000
Fragilaria sp.	13,000	11,000	11,000	4,200
Melosira sp.	57,000	55,000	53,000	12,000
Rhizosolenia sp.		690		
Surirella sp.	p[11]	p	p	
Centrales indet.	9,000	29,000	2,800	690
Pennales indet.	15,000	13,000		4,200
CHLOROPHYTA				
Scenedesmus sp.	p	690	p	
Pediastrum sp.	p	p	p	p
Spirogyra sp.	p			350
Staurastrum sp.	p			
Cosmarium sp.	1,000			
Closterium sp.	p		p	
Mougeotia sp.		690		1,800
CHRYSOPHYTA				
Dinobryon sp.	6,000	6,300	4,200	4,200

Table B-3A: (continued)

STATION	H-1**	H-2	I-5**	CS-2
CYANOPHYTA				
Anabaena sp.		p		p
Chroococcus sp.	p			
Gomphosphaeria sp.		p		p
Oscillatoria sp.	7,400	p	1,400	690
Microcystis sp.			690	
TOTAL NUMBER OF ORGANISMS	180,000	190,000	120,000	45,000

** Extremely dense population of very small coccoid cells, probably a yeast, present.

p[11] - present but less than 1000/l
p[12] - present but less than 690/l
p[13] - present but less than 690/l
p[14] - present but less than 350/l



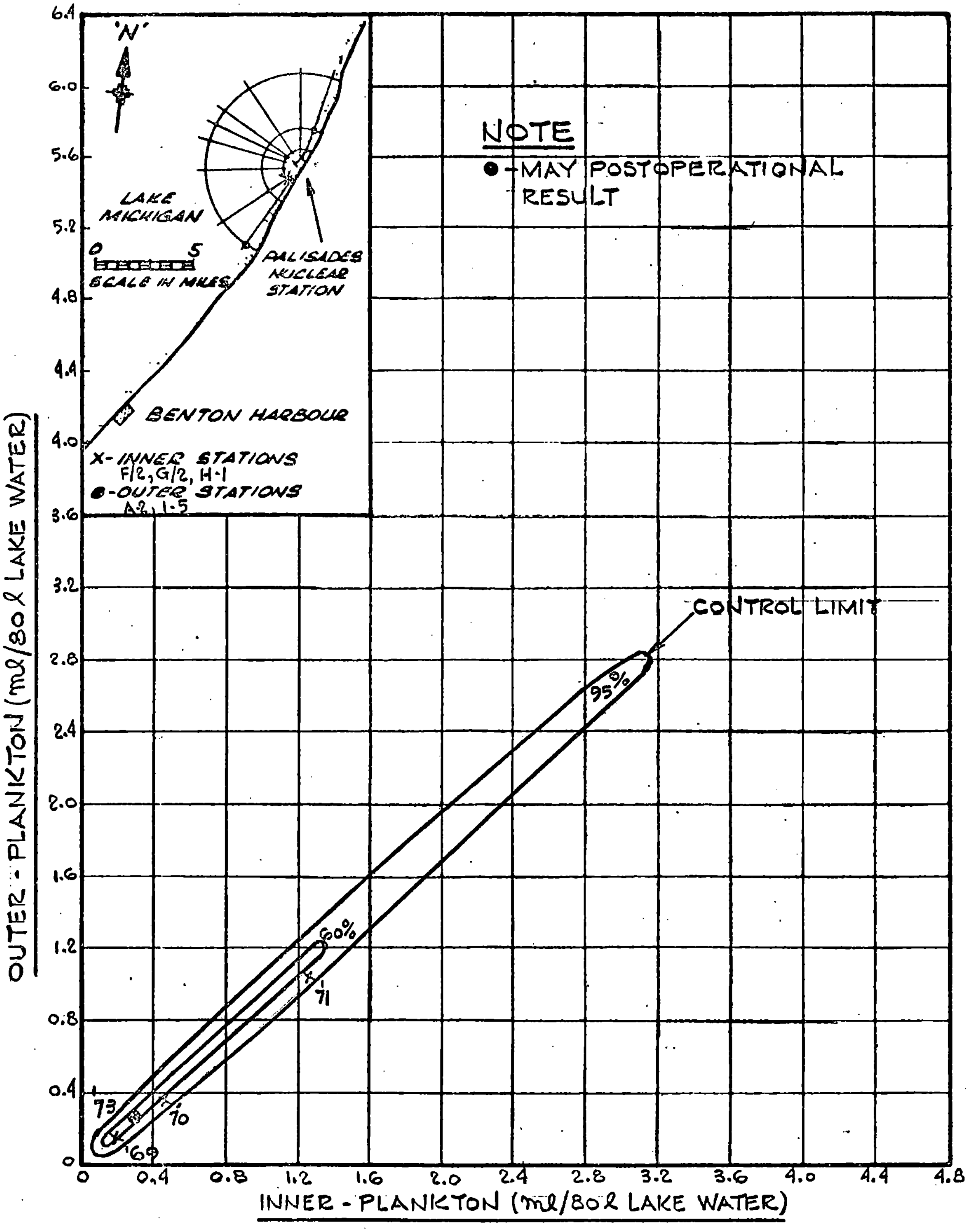
PLANKTON CONCENTRATION - DEPTH LESS THAN 20FT.

MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY B G. DATE 21-11-73 DWG No A 2048 -109	*FIG.* B-1A



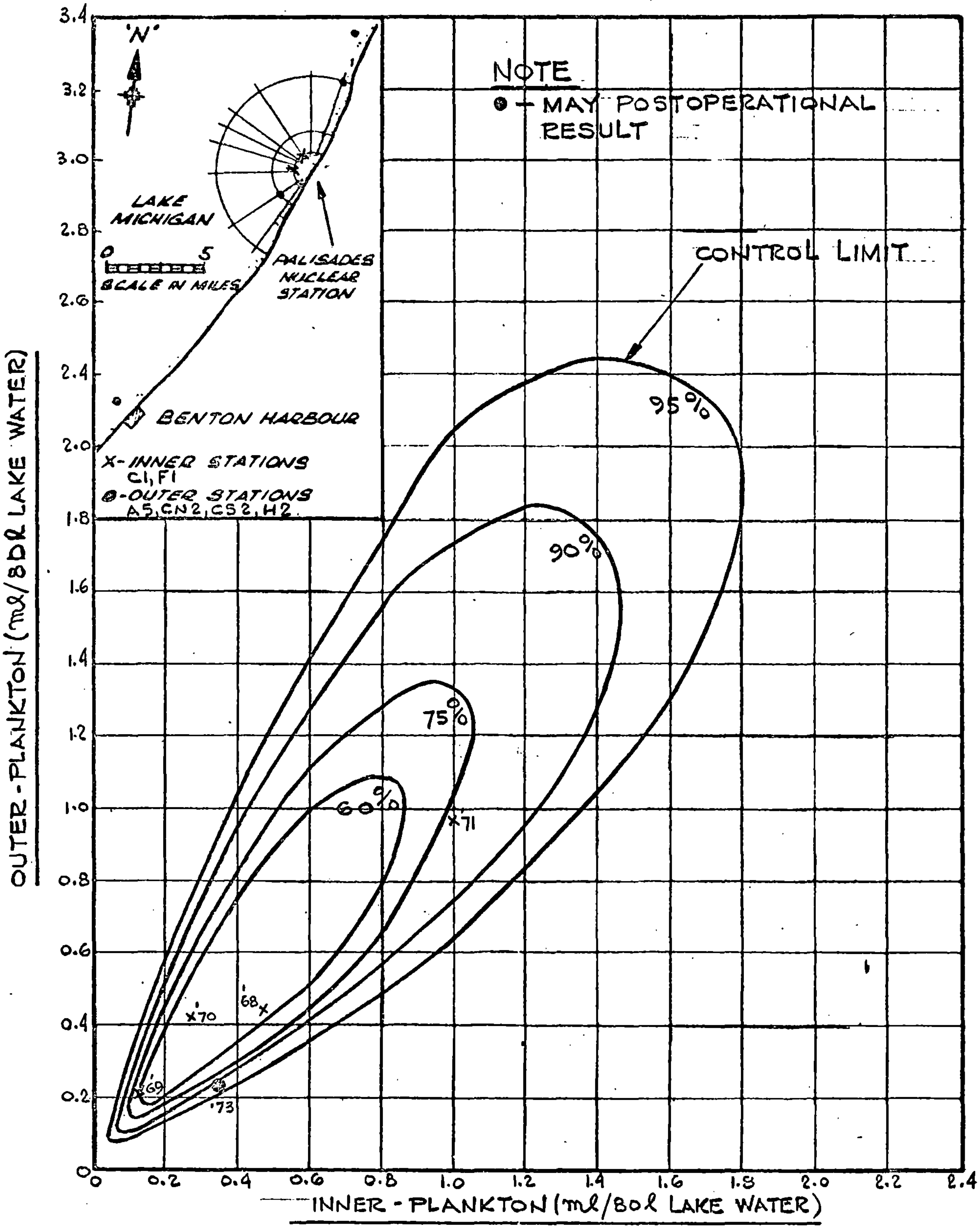
PLANKTON CONCENTRATION - SOUTH QUADRANT - DEPTH 20-30 FT.

MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY B G. DATE 21-11-73 DWG NO *A 2048 -108*	*FIG.* B-2A



PLANKTON CONCENTRATION - DEPTH 30 - 50 FT.

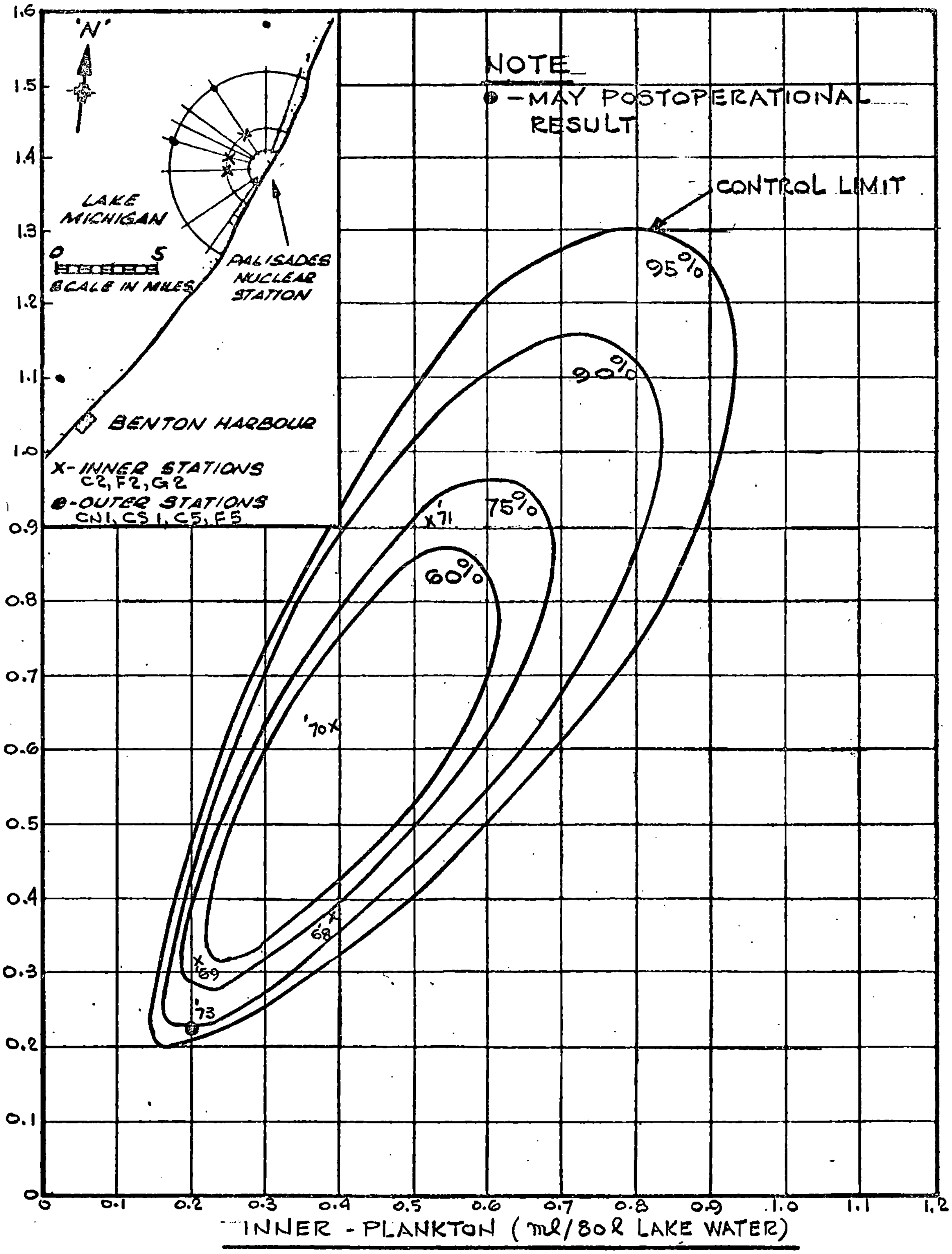
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY DATE 17-10-73 DWG NO A2048-101	FIG. B-3A

TRANSLAR 003



PLANKTON CONCENTRATION - DEPTH GREATER THAN 50FT.

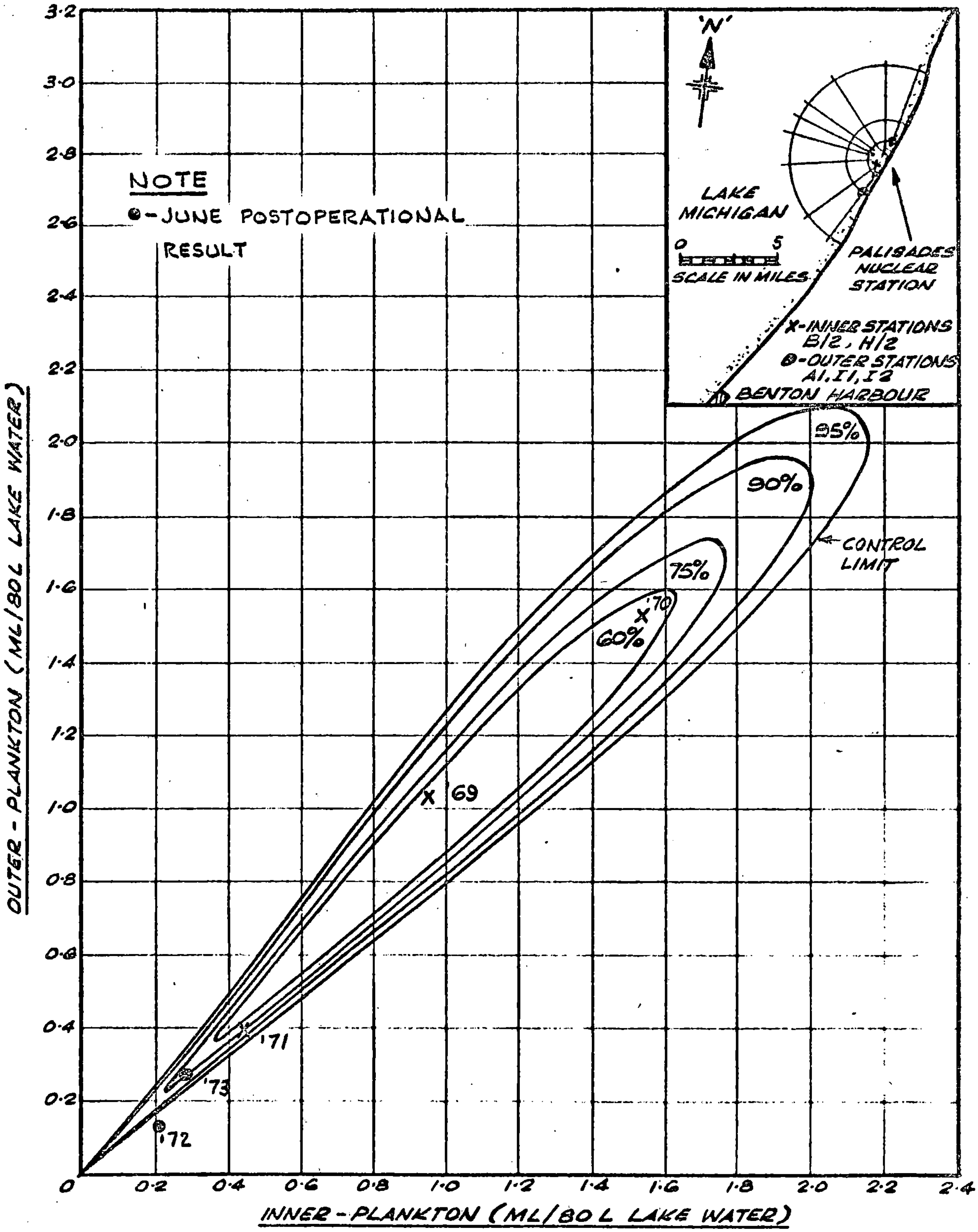
MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO A 2048-102	*FIG.* B-4A

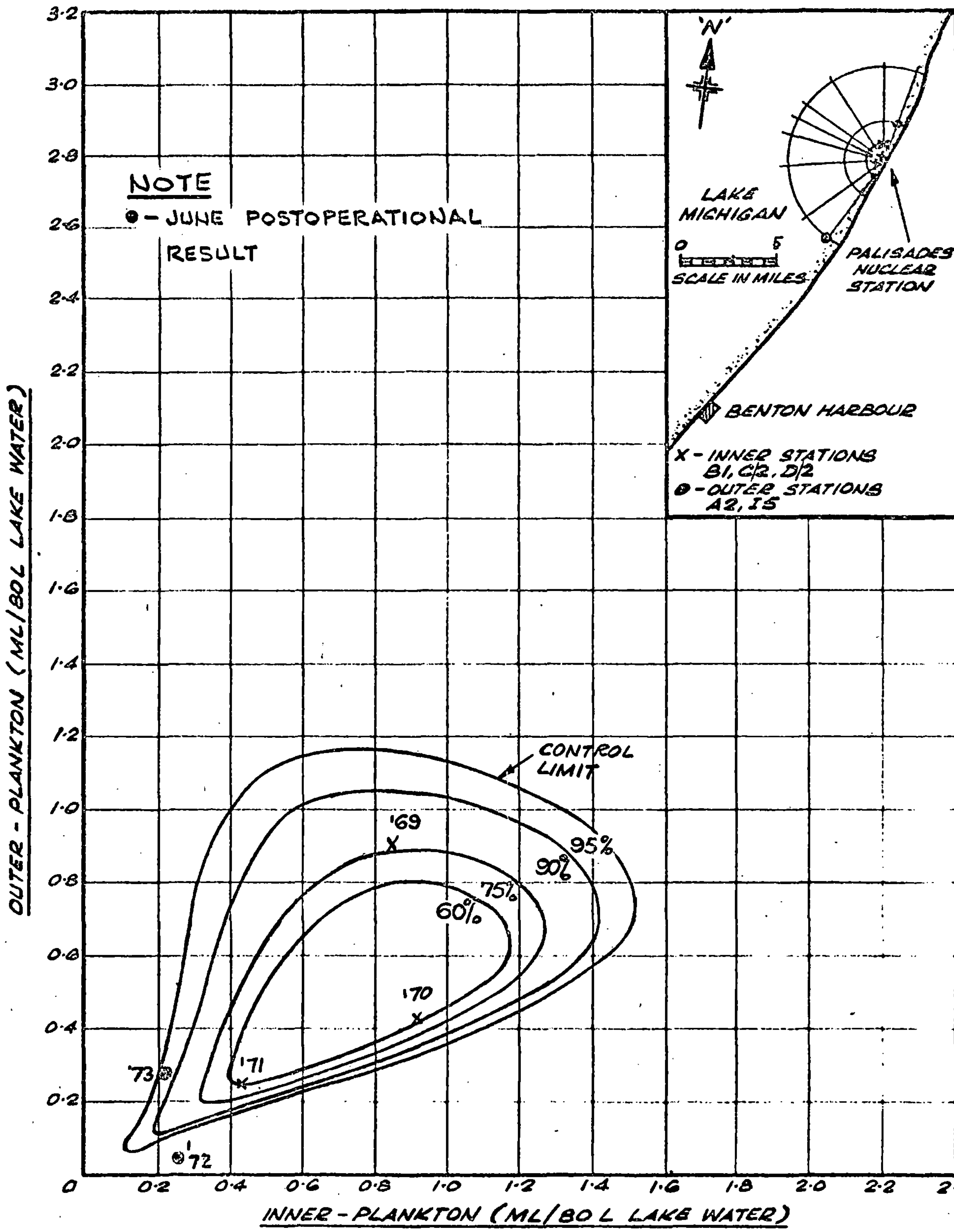
TRANSLAR 003



PLANKTON CONCENTRATION - DEPTH LESS THAN 20 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 14/73 DWG NO A 2048-49	FIG. B-5A

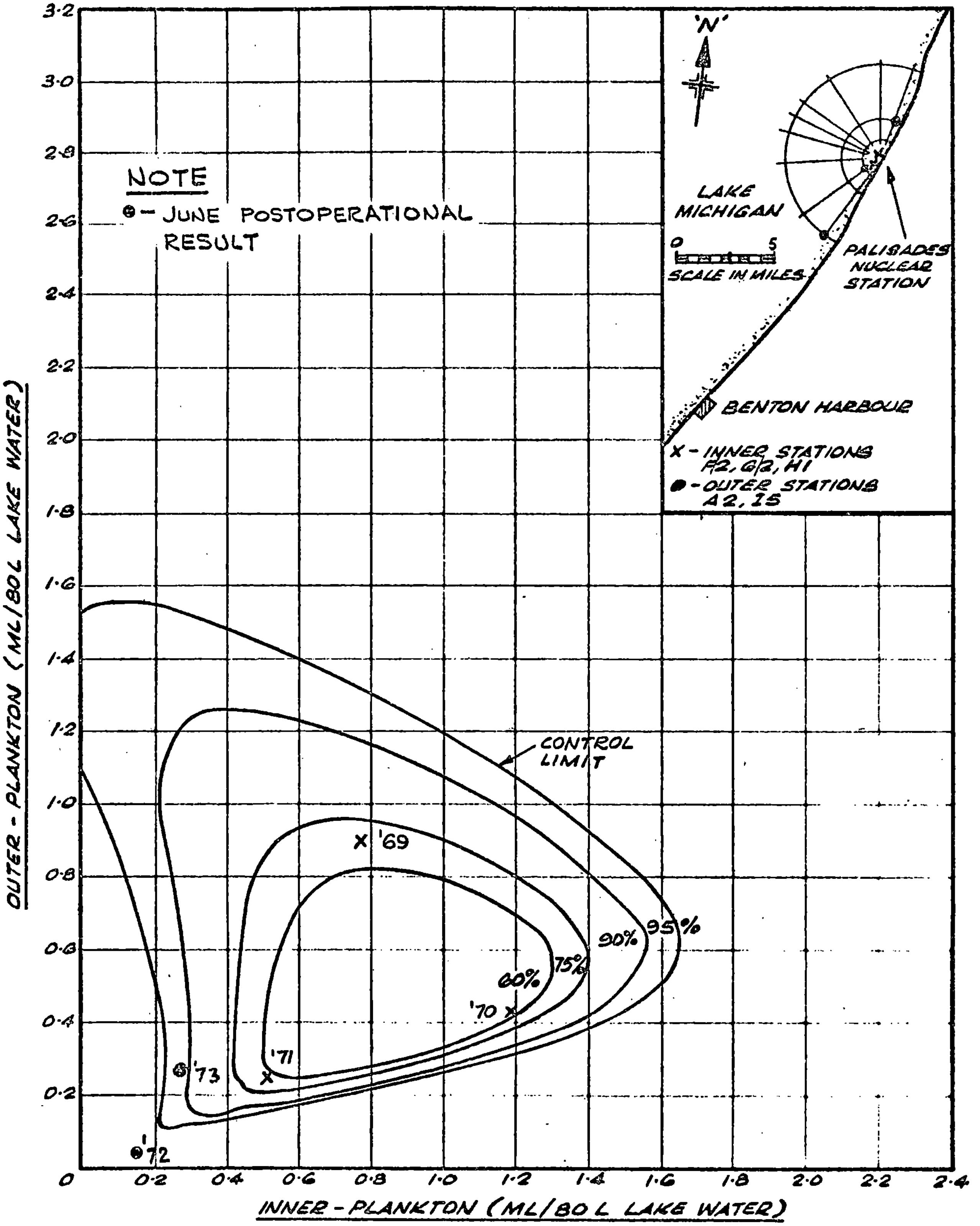
TRANSLAR 003



PLANKTON CONCENTRATION - NORTH QUADRANT - DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DWG NO A 2048-50	DATE JAN 14/73	FIG. B-6A

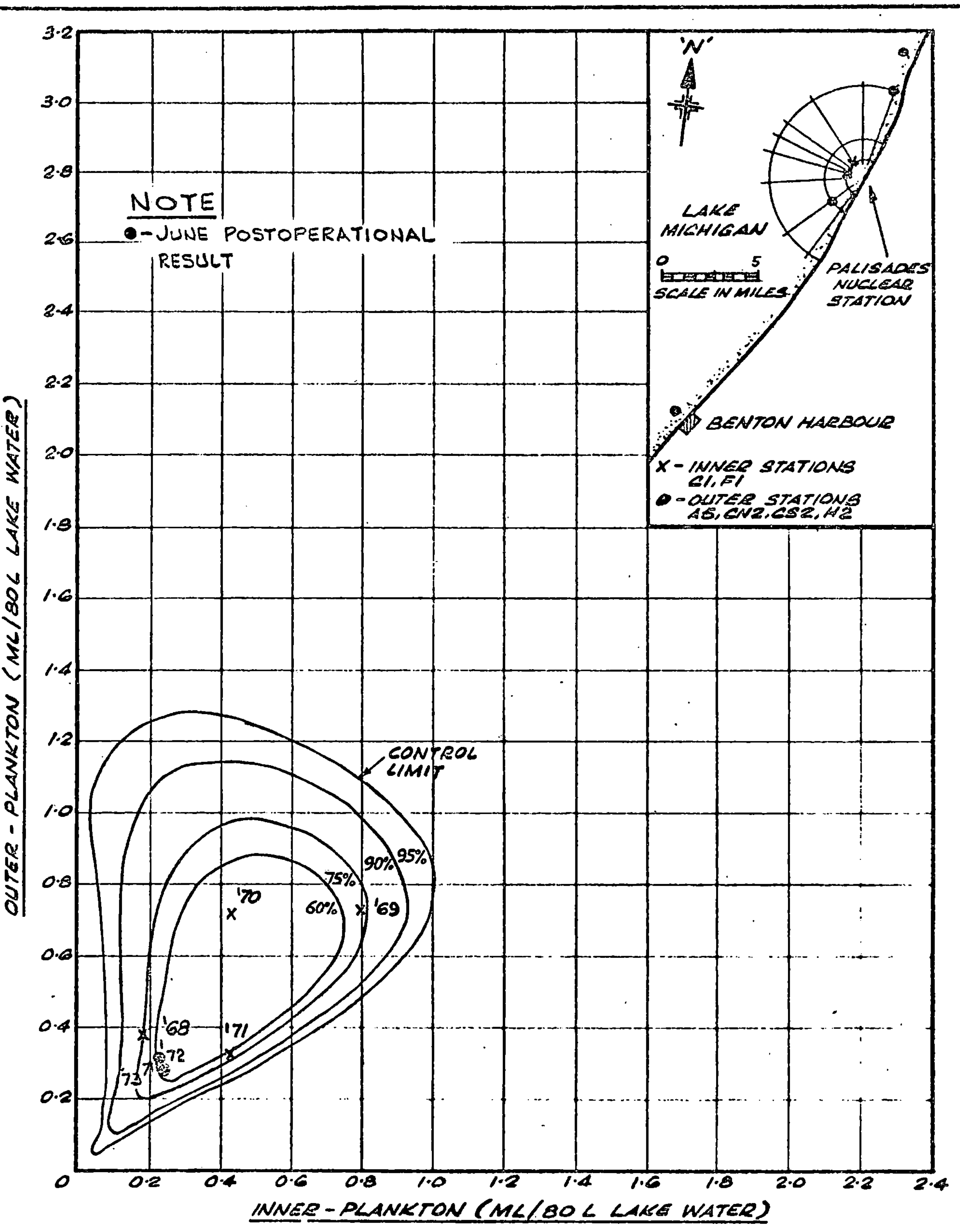
TRANSLAR 003



PLANKTON CONCENTRATION - SOUTH QUADRANT - DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

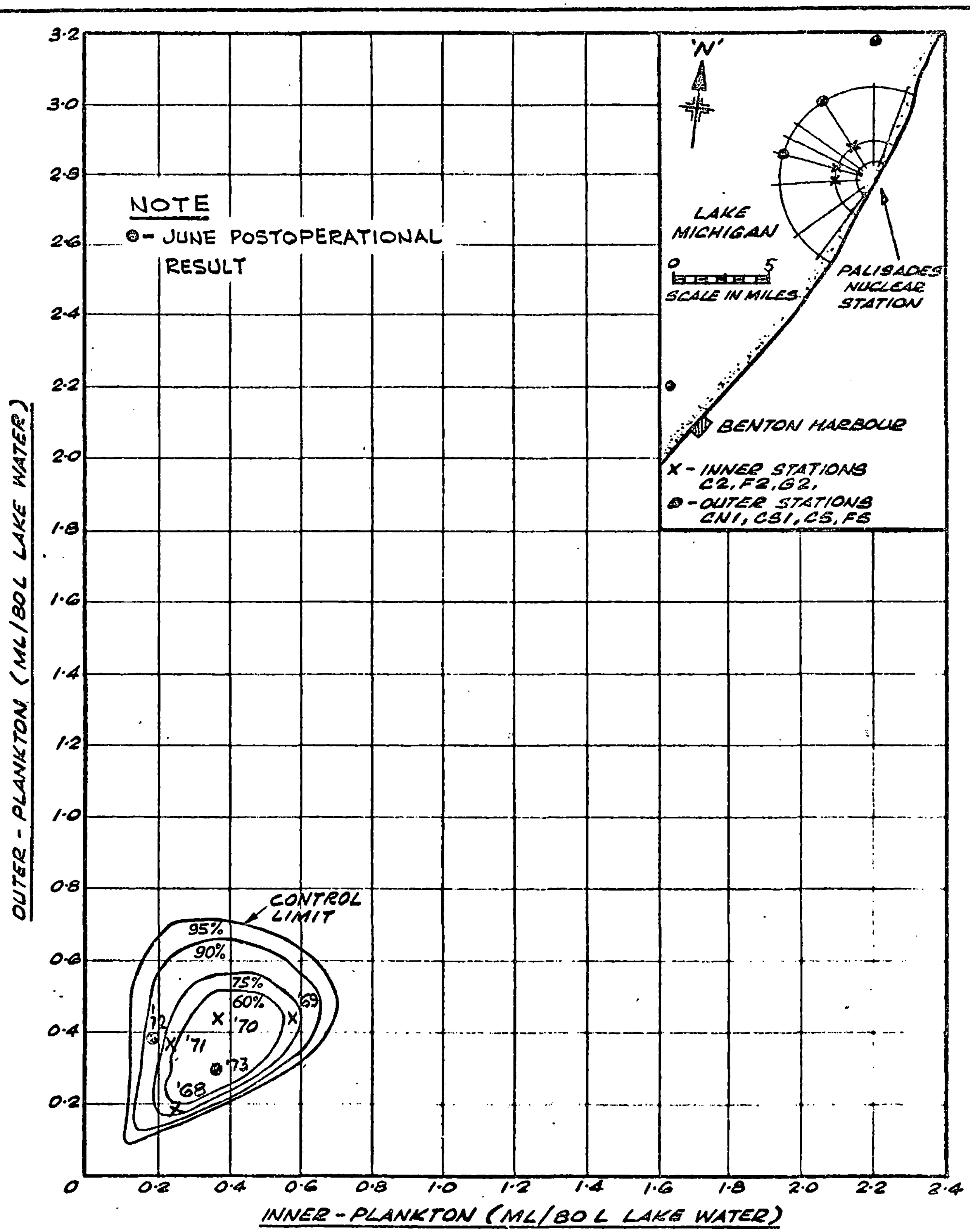
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 14/73 DWG NO A 2048-51	FIG. B-7A

TRANSLAR 003



PLANKTON CONCENTRATION - DEPTH 30-50 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

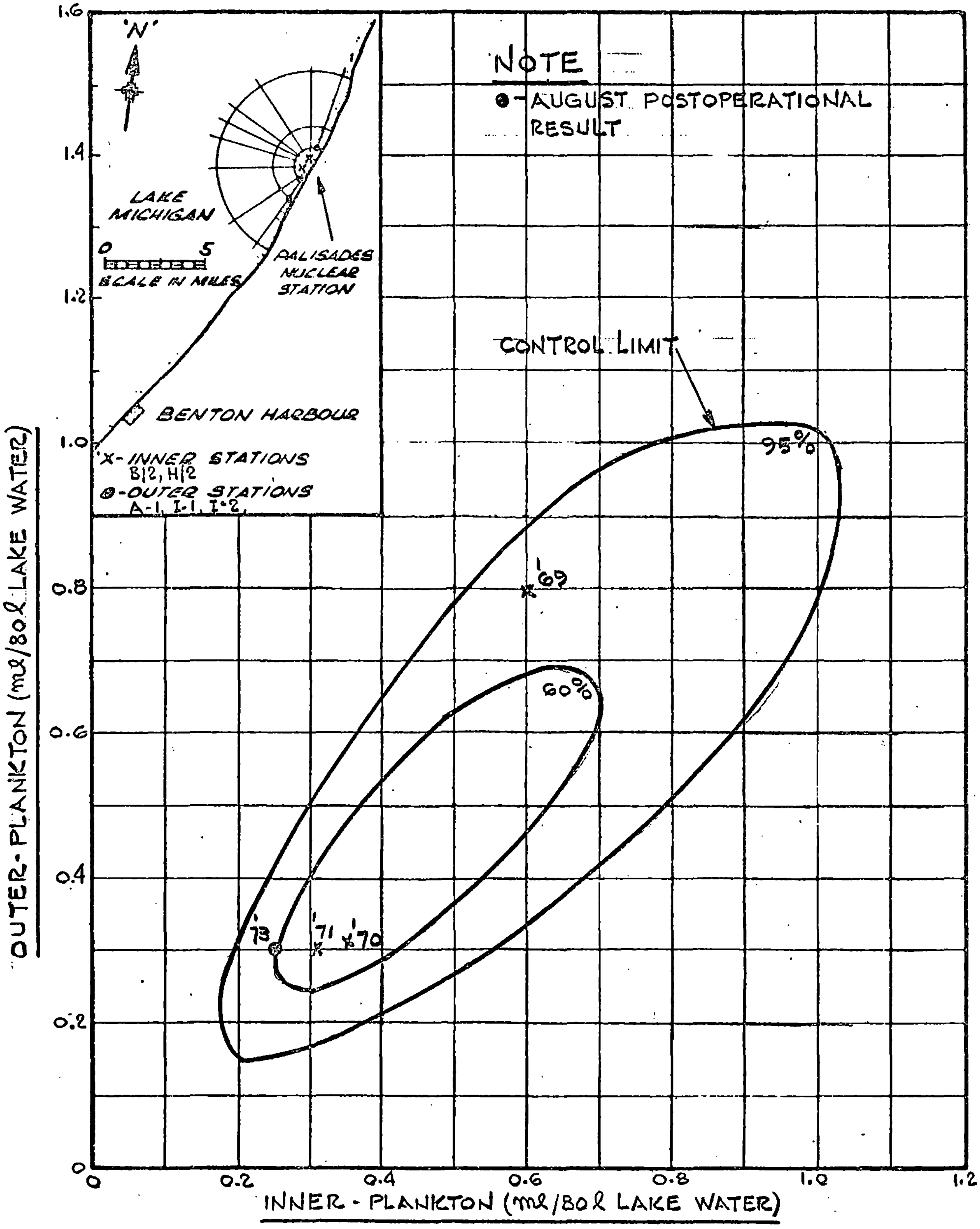
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 12/73 DWG NO A 2048-52	FIG. B-8A



PLANKTON CONCENTRATION - DEPTH GREATER THAN 50FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 12/73 DWG NO A 2048-53	FIG. B-9A

TRANSLAR 003



PLANKTON CONCENTRATION - DEPTH LESS THAN 20 FT.

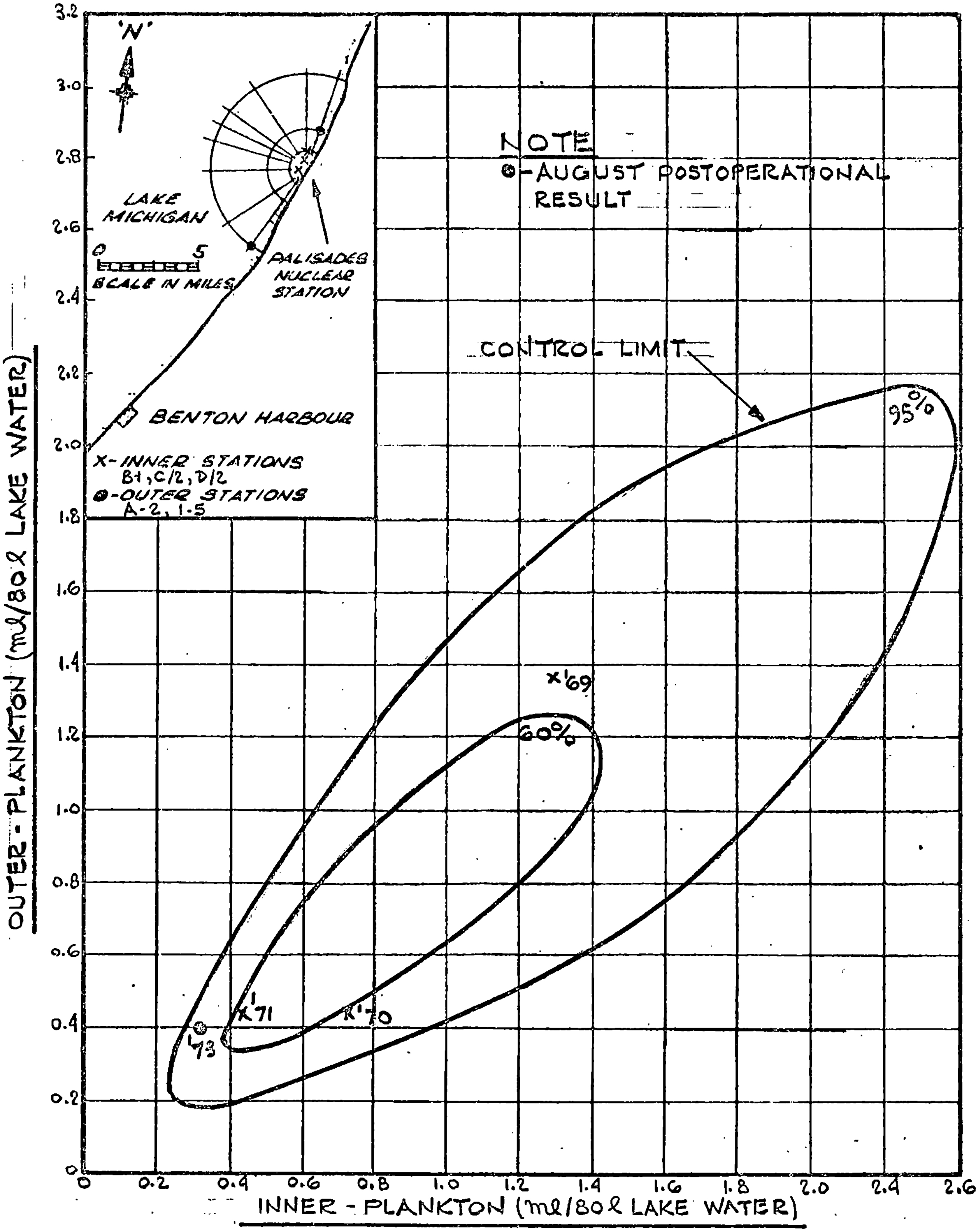
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY B G DATE 21-11-73 DWG NO *A 2048-107*	*FIG.* B-10A

TRANSLAR 003



PLANKTON CONCENTRATION – NORTH QUADRANT – DEPTH 20-30 FT.

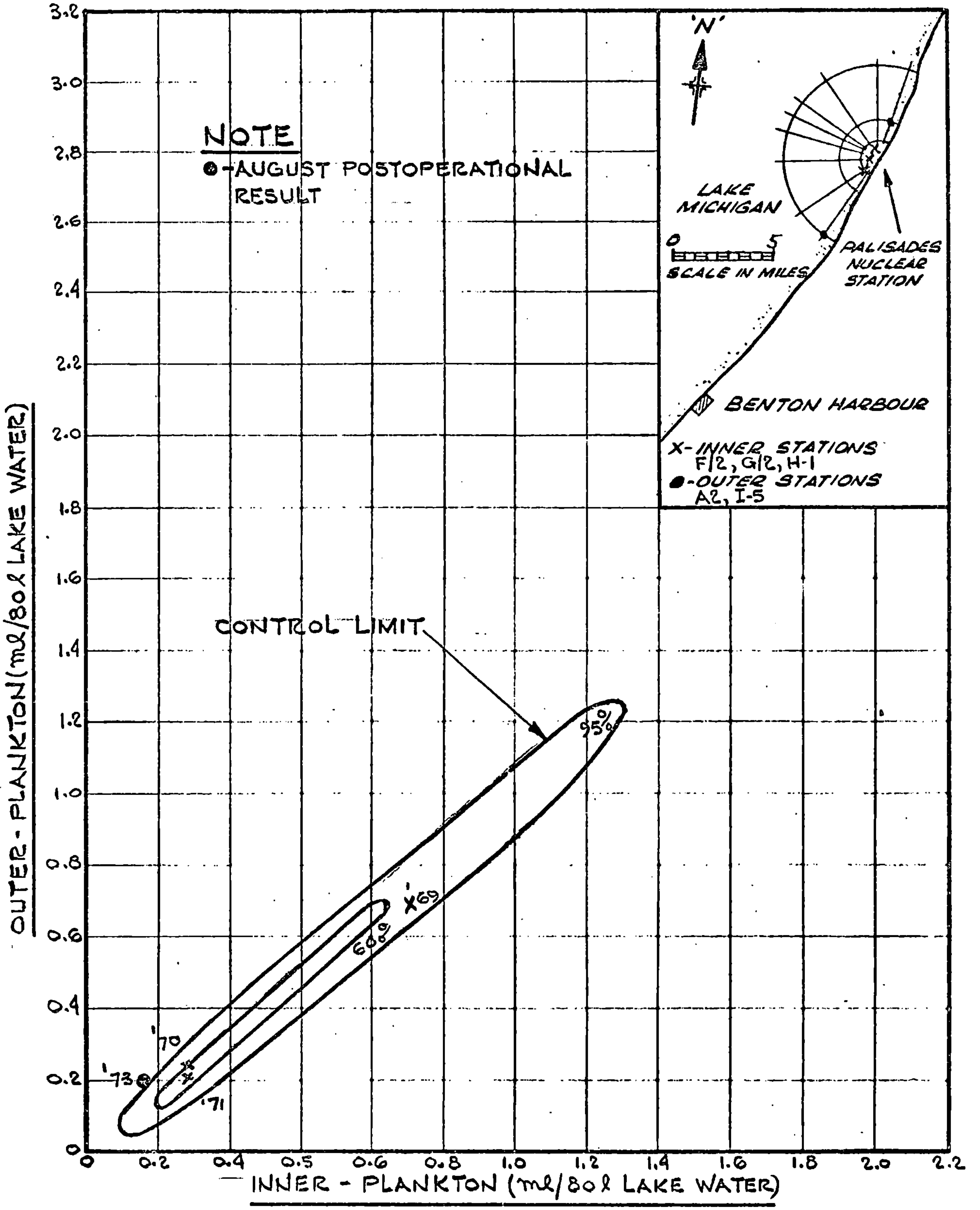
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON – MICHIGAN*	BEAK	BY BG DATE 21-11-73 DWG NO A 2048-106	FIG. B-11A

TRANSLAR 003



PLANKTON CONCENTRATION - SOUTH QUADRANT - DEPTH 20-30 FT.

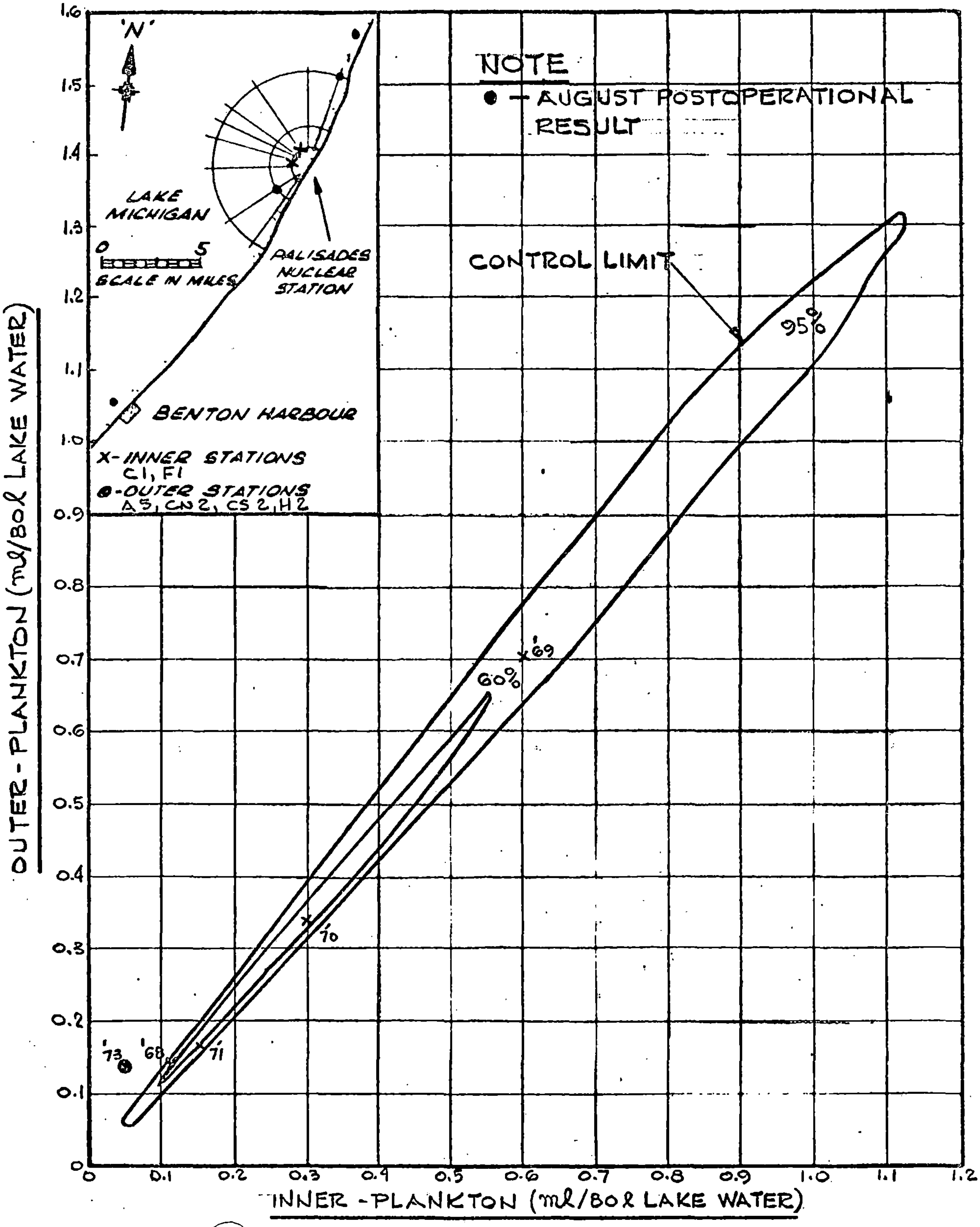
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY B G. DATE 21-11-73 DWG NO *A 2048 - 105*	*FIG.* B-12A

TRANSLAR 003



PLANKTON CONCENTRATION - DEPTH 30-50 FT.

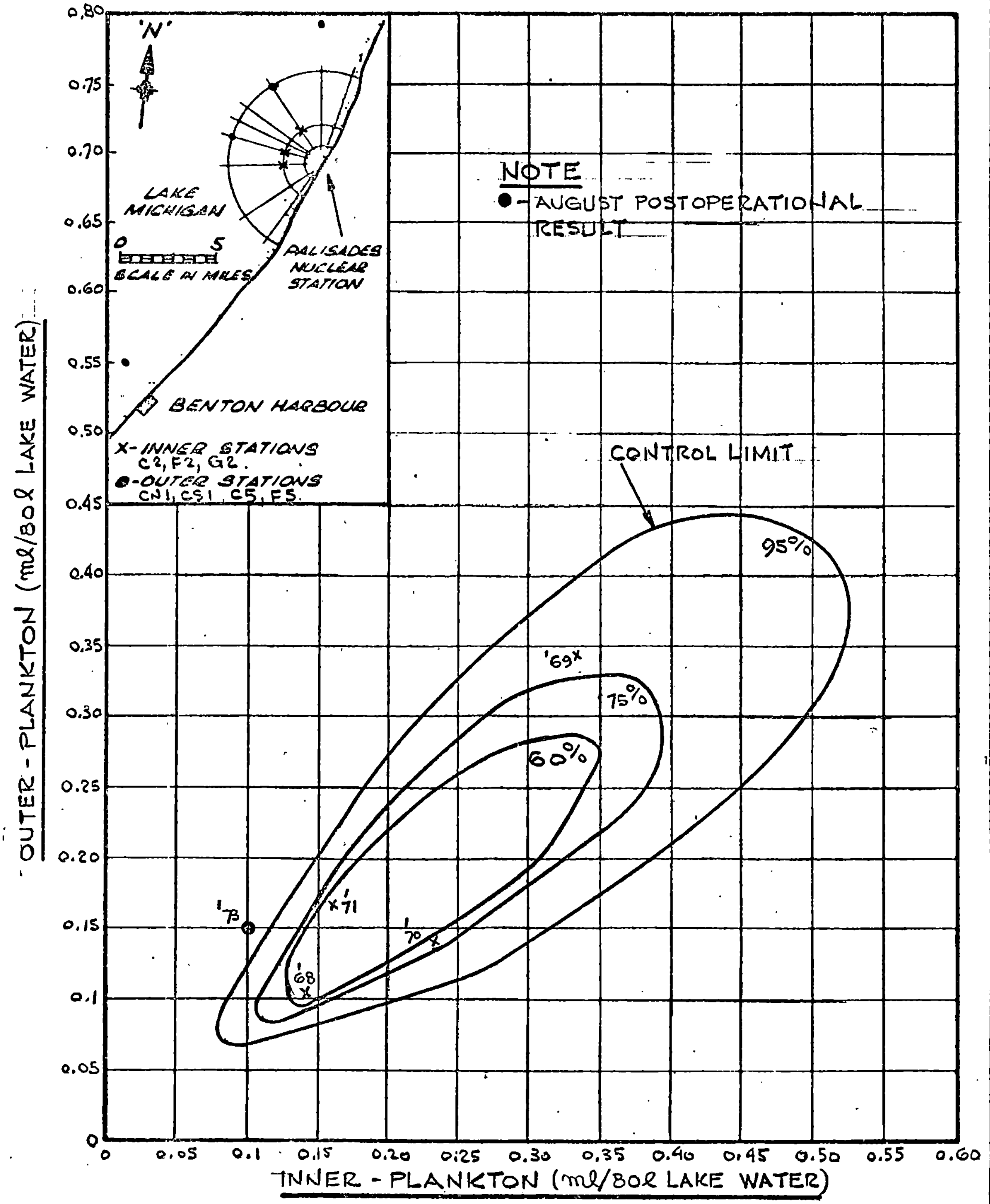
AUGUST BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY DATE 17·10·73 DWG NO A 2048 -103	FIG. B-13A

TRANSLAR 003



PLANKTON CONCENTRATION - DEPTH GREATER THAN 50 FT.

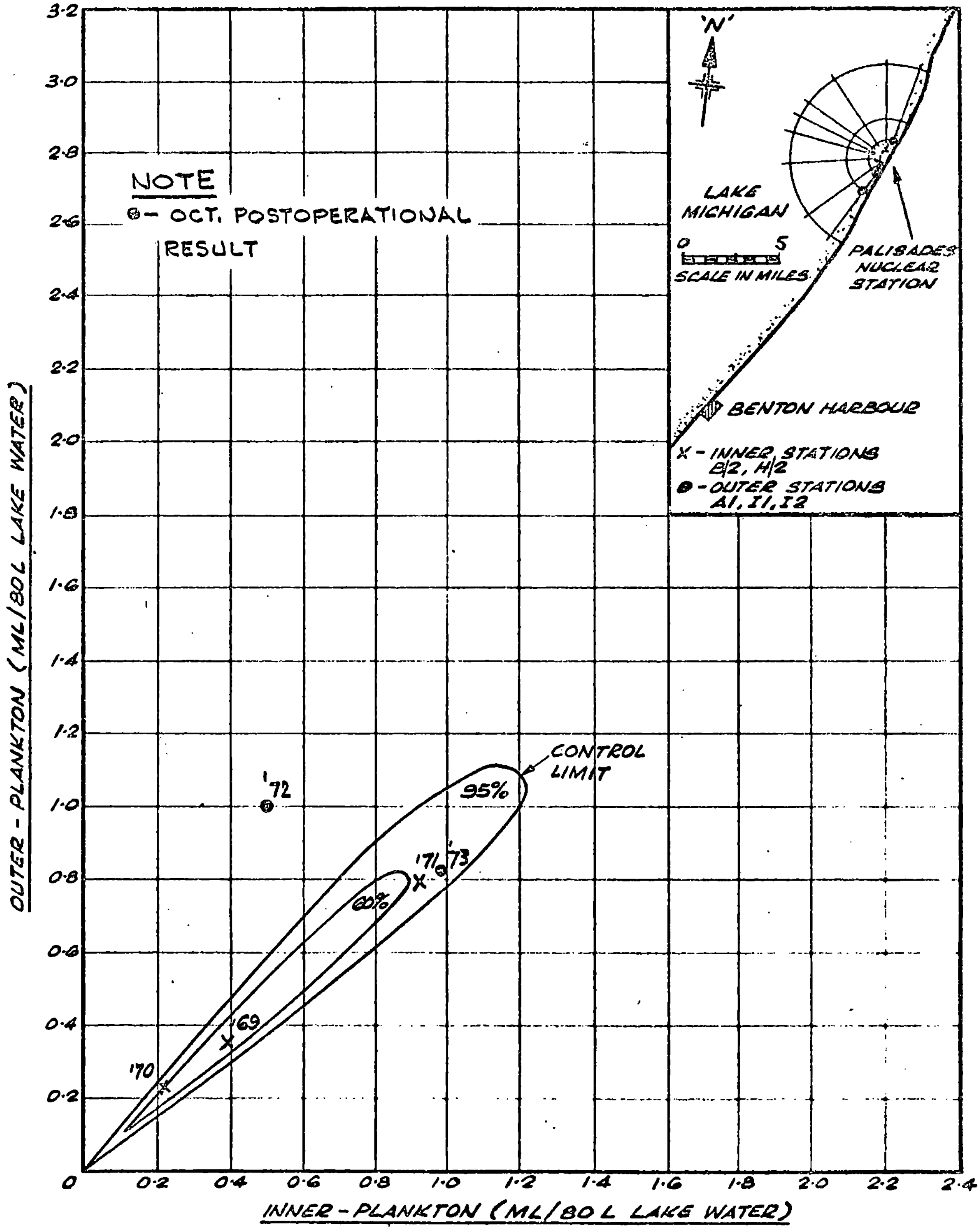
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO A 2048 -104	FIG. B-14A

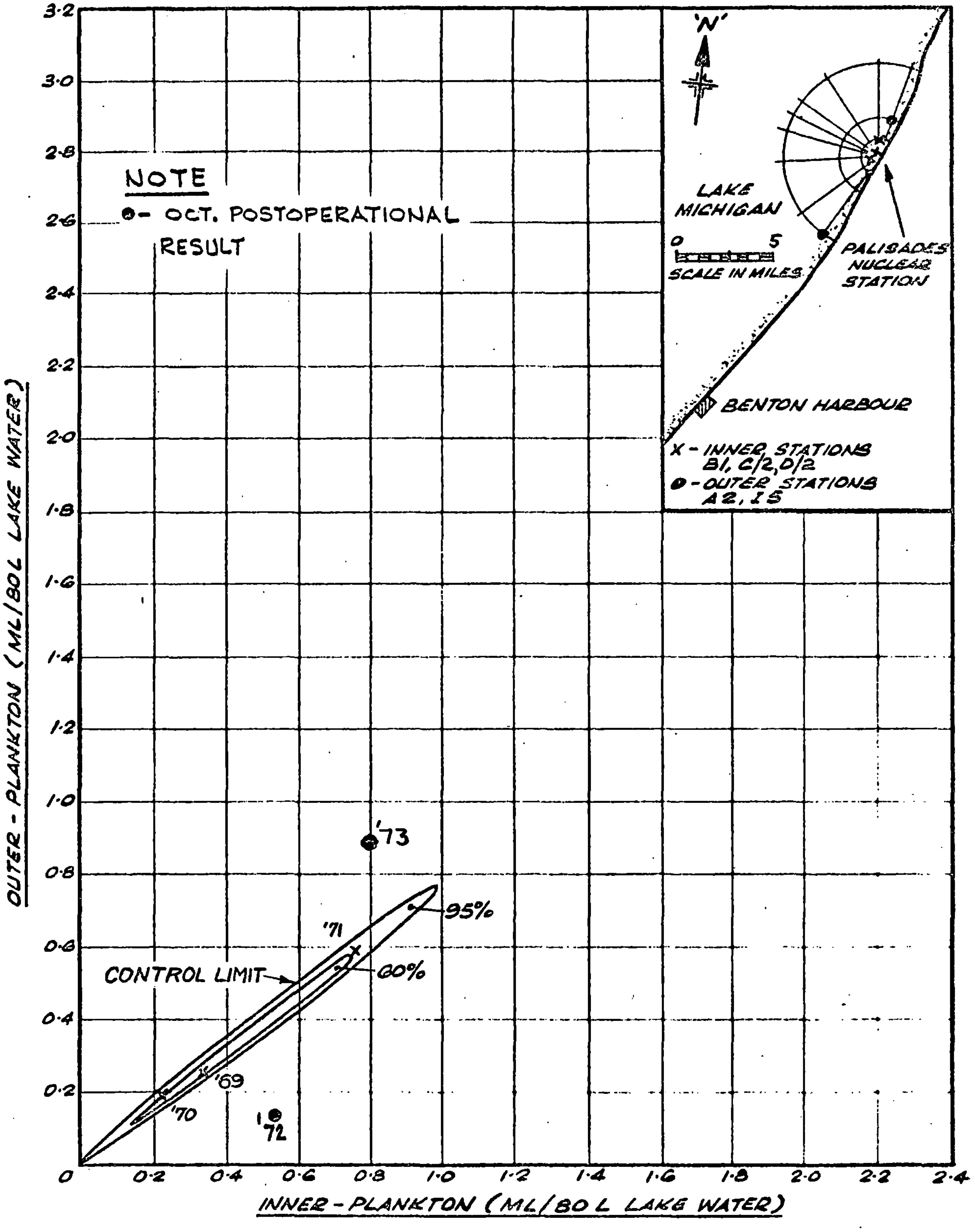
TRANSLAR 003



PLANKTON CONCENTRATION - DEPTH LESS THAN 20FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DWG NO A 2048-54	DATE JAN 14/73	FIG. B-15A

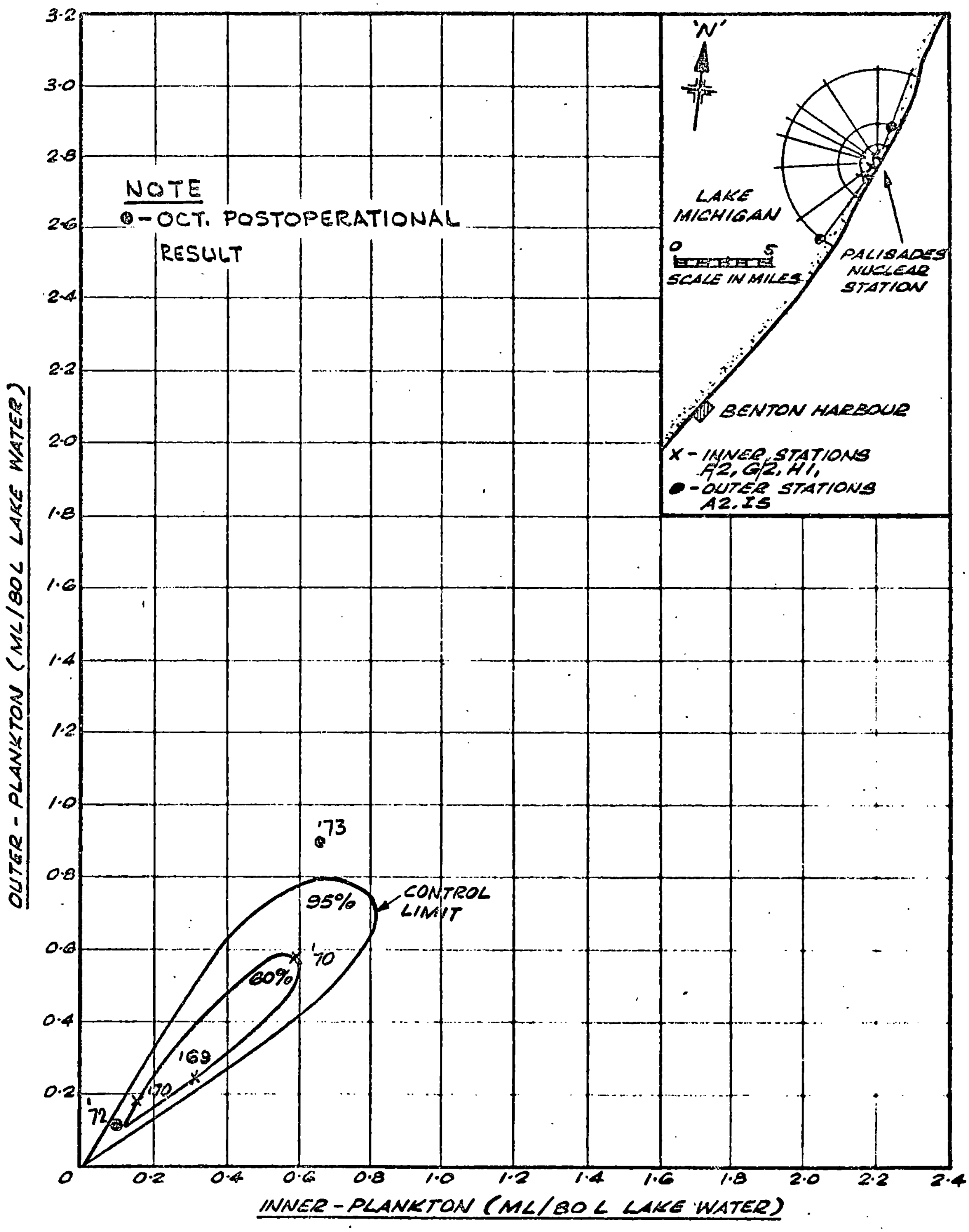
TRANSLAR 003



PLANKTON CONCENTRATION - NORTH QUADRANT - DEPTH 20-30 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON – MICHIGAN	BEAK	BY RCD DATE JAN 14/73 DWG NO A 2048-55	FIG. B-16A

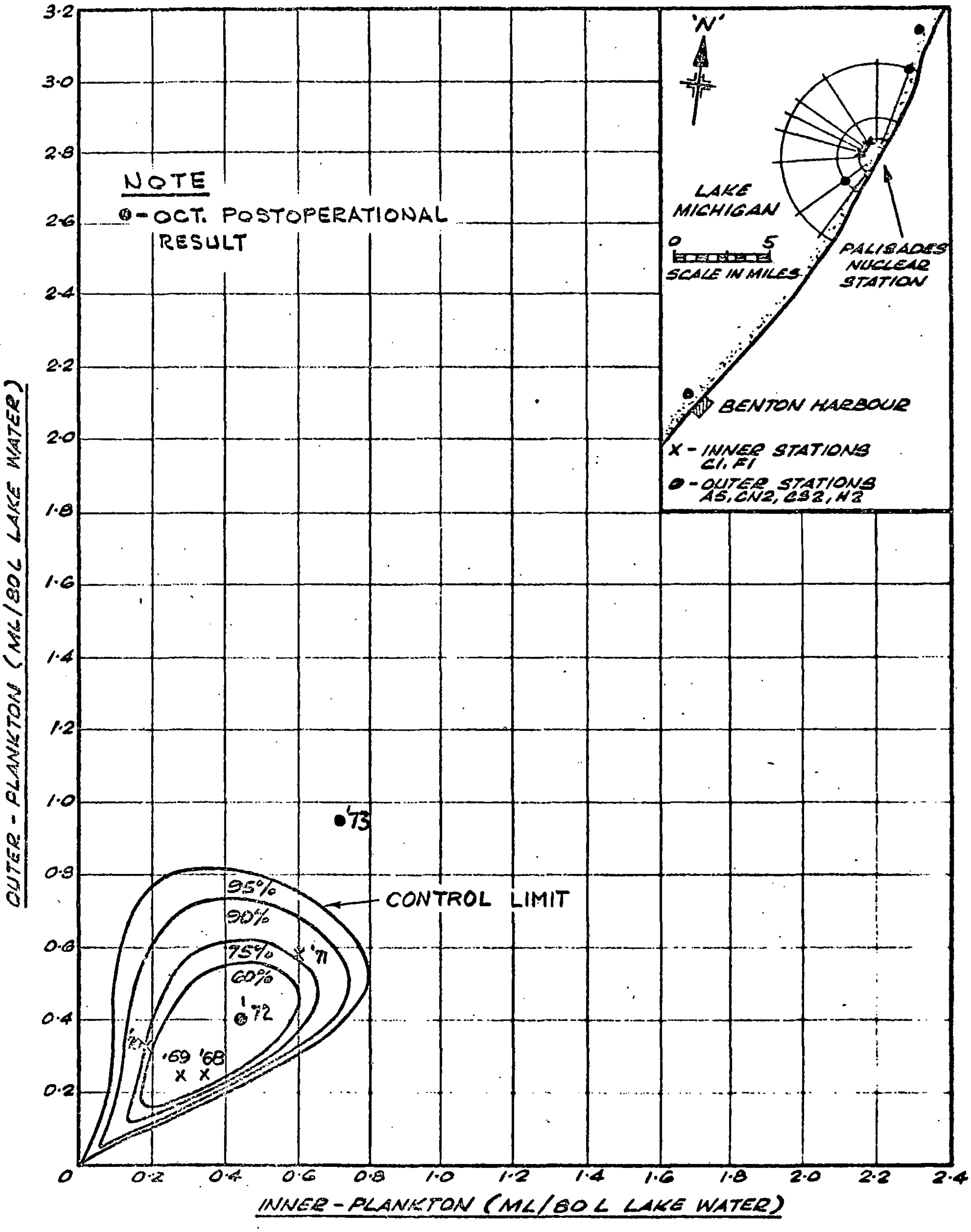
TRANSLAR 003



PLANKTON CONCENTRATION - SOUTH QUADRANT - DEPTH 20-30 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

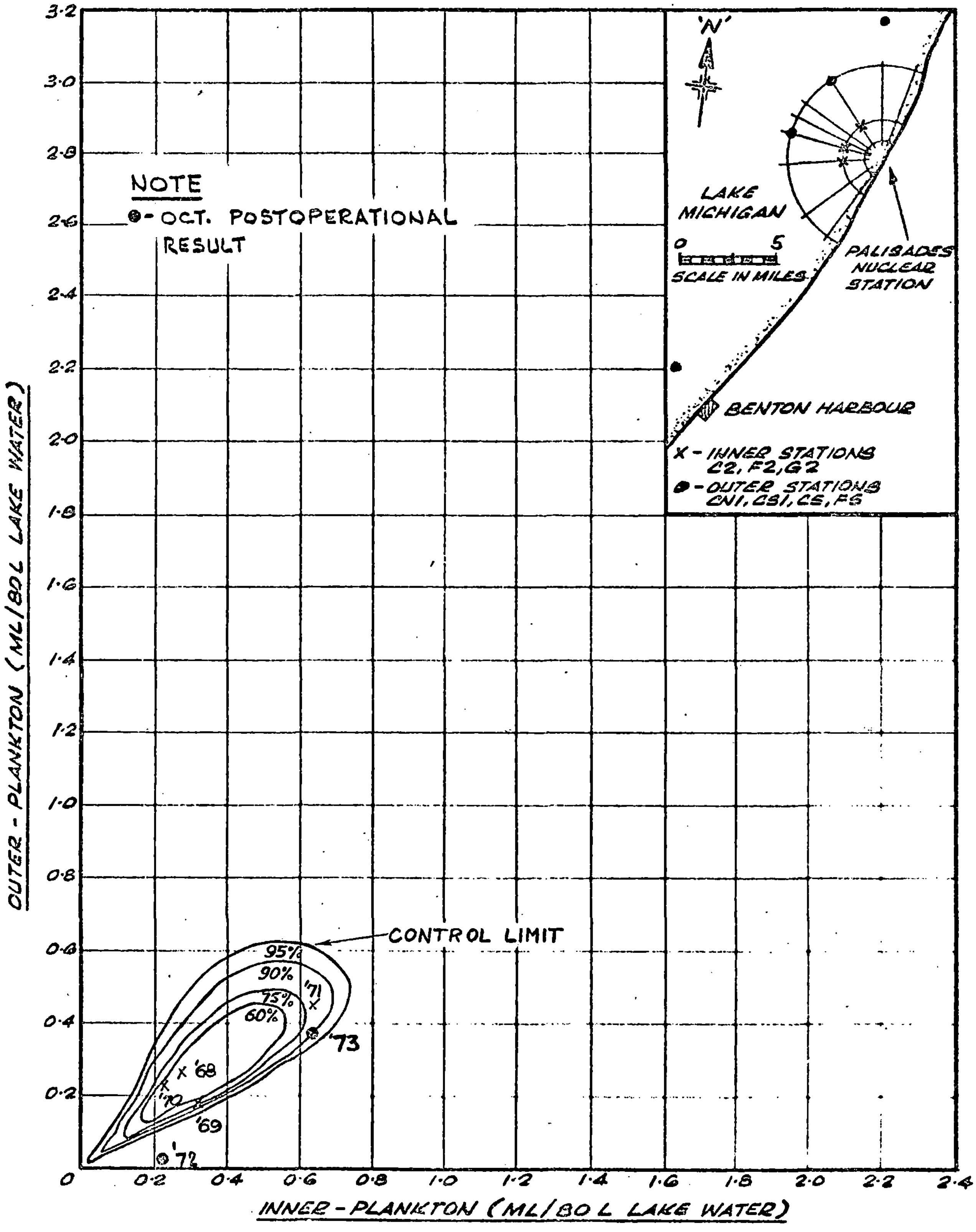
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD	DATE JAN 14/73	FIG.
		DWG NO A 2048-56		B-17A

TRANSLAR 003



PLANKTON CONCENTRATION - DEPTH 30-50 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 12/73 DWG NO A 2048-57	FIG. B-18A



PLANKTON CONCENTRATION - DEPTH GREATER THAN 50FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN. 12/73 DWG NO A 2048-58	FIG. B-19A

KEY TO DATA LOCATIONS - BENTHOS

1. Benthos Data and Control Chart Comparisons 1968-71 - Semiannual Operations Report #5, App A.

2. Benthos Data and Control Chart Comparisons 1972 - Semiannual Operations Report #5, App B.

3. Benthos Data and Control Chart Comparisons 1973 - Semiannual Operations Report #6, App A.

4. Benthos - Summary of Significant Changes and Control Chart Comparisons 1968-1974 - Attached Text and Figures C-1A Through C-81A.

5. Pre- and Postoperational Biomass Determinations on Amphipods and Oligochaete Samples - Attached Appendix Ca.

1974 SURVEY - BENTHOS

The following section contains a discussion of the final control charts which carry the results of the small scale survey of 1974. Of the 40 stations surveyed prior to 1974, only the following 14 were sampled: A-2, A-5, B-1, C/2, C-1, D/2, F/2, F-1, G/2, H-1, H-2, 1-5, CN2 and CS2.

RESULTS

Changes in population density for the Inner groups of stations were indicated on the control charts as being significant in 1973 for chironomids at 30 to 50 feet in June, for oligochaetes at stations with depths greater than 50 feet in August and also at 20- to 30-foot depths south of the discharge in October, and for sphaeriids at 30- to 50-foot depths in October. The benthos at stations with depths over 50 feet were not considered to be directly influenced by the thermal plume so were not sampled in the 1974 survey.

Stations where changes had occurred in both Inner and Outer groups of stations were also studied and are given in the following table:

June	
Oligochaetes	- 20 to 30 Ft S
Amphipods	- 20 to 30 Ft S

August	
Oligochaetes	- 0 to 20 Ft
Chironomids	- 20 to 30 Ft S
Chironomids	- 30 to 50 Ft
Sphaeriids	- 20 to 30 Ft S

October	
Oligochaetes	- 30 to 50 Ft
Chironomids	- 20 to 30 Ft N
Amphipods	- 20 to 30 Ft N
Amphipods	- 20 to 30 Ft S
Amphipods	- 30 to 50 Ft

Amphipoda - 20- to 30-Foot Depth

Both charts represented the densities of Pontoporeia hoyi at depths between 20 and 30 feet. Densities for this organism had always been low at these stations and the June results continued to lie inside the control limits of the chart for stations lying north of the discharge (Figure C-1A) and returned in 1974 to lie inside the control limits of the chart representing stations south of the discharge (Figure C-2A), after being just outside the control limits in June 1973.

A statistical analysis of the biomass of the amphipods at the five stations composing the south quadrant chart was conducted to determine whether

populations at stations within the area of the plume were exhibiting an overall decrease in size as well as numbers. No significant differences were found between the means of the preoperational and postoperational biomass. (See Appendix Ca.) As the June 1974 results lay within the control limits, the small changes noted in June 1973 were concluded to be natural phenomena. Depths of water of 20 to 30 feet never contained large numbers of P hoyi.

The August charts for the stations discussed in the previous paragraph had results which lay within the control limits in 1973. There were no significant changes in amphipod densities in August 1974 in the south quadrant (Figure C-11A). An increase at Outer stations in the north quadrant (Figure C-10A) caused the August 1974 result to lie just outside the control limits but within the extended limits of both sets of stations. The 1974 October survey was abandoned, so the amphipod populations at the 20- to 30-foot depths could not be studied further. As the October 1973 densities were very low (Figures C-15A, C-16A), an investigation of the biomass was considered, but animals were too few to make this a meaningful study. After 1968, the October Inner amphipod densities were more stable than those at the Outer stations. The relative positions of the annual results on the two charts were very similar and pointed to a change which was occurring at the same water depths along at least a seven-mile stretch of shoreline, both north and south of the discharge. The changes in density were considered to be a natural phenomenon.

Amphipoda - 30- to 50-Foot Depth

All June postoperational amphipod densities at the 30- to 50-foot depth range lay within the control limit (Figure C-7A). The density of both Inner and Outer stations had more than doubled in 1974 over the two previous postoperational years. A large number of the animals were noted as being small young of the year. The August figure lay within the control limits (Figure C-12A) with reduced numbers from those of June.

Amphipod densities for October 1972 and 1973, at stations in the 30- to 50-foot depth range (Figure C-17A), were outside the control limit in both postoperational years, but still within the projected limits for both Inner and Outer groups. There had been a steady drop in the preoperational Inner densities from the initiation of the study, with possibly a halt in this trend in 1973, as there was very little difference between the two postoperational densities. The condition of the amphipods was studied using biomass, to determine whether this had deteriorated together with the decrease in density, but no significant differences in biomass were found. (See Appendix Ca.)

As the postoperational results were within the projected control chart limits, the decreases had occurred at both Inner and Outer stations. The changes, which were similar to those occurring in populations at other shallow stations, were probably due to broad environmental effects. Low numbers of amphipods were also recorded at stations with similar depth ranges and substrate type in the Donald C. Cook Plant preoperational surveys.[1]

Chironomidae - 20- to 30-Foot Depth

Chironomid densities shown on the control chart for depths of 20 to 30 feet in the north quadrant of the survey grid were within chart control limits in June 1974 (Figure C-25A) and August 1974 (Figure C-30A). Changes which had occurred in October (Figure C-35A) at these stations in 1973 were caused by increases at both Inner and Outer groups of stations, and could not be followed up in 1974 as the October survey was abandoned.

The charts for the south quadrant in the 20- to 30-foot depth zone showed both June (Figure C-26A) and August (Figure C-31A) 1974 results lying within the control chart. In August 1973, the result lay just outside the control limits and was thought to be due to natural fluctuations as small decreases had occurred at the Inner and Outer groups of stations since 1971. There was no August survey in 1972.

Chironomidae - 30- to 50-Foot Depth

A significant increase in chironomid densities occurred at the 30- to 50-foot depth zone in both June 1973 and 1974 (Figure C-27A). Detailed analysis showed this to be caused by one genus, Polypedilum sp. By August 1973 (Figure C-32A), the Inner chironomid densities had returned to within the Inner control limits but the Outer density was still greater than pre-operational levels. In August 1974, the density at the Inner and Outer had greatly increased with an average of 82 per square foot at the Outer stations and 71 per square foot at the Inner. This increase was caused by Chironomus sp. Further statistical analysis, as discussed in Section C, indicated that for the whole postoperational period these increases were not significant for either genus at any of the stations represented by the chart. Statistical analysis using the Mann-Whitney test, for the month of June only, showed (as the chart had illustrated) a definite statistically significant increase in Polypedilum density at one of the stations, C-1. In October 1973 the 1973 density lay within the control limits.

Oligochaeta

Significant changes occurred in the oligochaete populations at stations with depths greater than 50 feet in August, and at stations with depths of 20 to 30 feet south of the discharge in October. As the former stations were at least two miles from the discharge, they were not considered critical for further study in 1974. Also taken into consideration was the fact that the changes had occurred at both Inner and Outer stations.

Oligochaeta - 20- to 30-Foot Depth

The chart for June (Figures C-43A and C-44A) showed that the Inner and Outer station densities both north and south of the discharge had increased considerably. The 1974 point lay within the control limits but at a higher density than for any of the other surveys.

The August 1974 densities for Inner stations showed a further increase over June. The Outer densities decreased from those in June 1974, but were similar to 1973 August levels.

To determine whether the condition factor of the oligochaetes had also increased, biomass determinations were done on some of the samples comparing pre- and postoperational surveys, but no significant differences between preoperational and postoperational biomass were found. (See Appendix Ca.)

The control chart for oligochaete densities at stations lying south of the discharge in 20- to 30-foot depths were all within limits and showed significant increases in October 1972 and 1973 (Figure C-34A). After a low density in October 1970, there had been a steady increase at the Inner stations. The overall trend seems to be that of natural fluctuations, the densities remaining within expected limits in the earlier part of the year, but with overall higher levels being maintained. Changes in October were larger than had been occurring in that month prior to start-up of generating operations. The survey by Ayers and Seibel[1] showed oligochaetes to be locally abundant in the autumn. The Mann-Whitney test, used to show significant changes in the population densities of individual organisms at each station, showed a significant increase at F/2 and H-1, both of which are presented in this chart (Figure C-54A).

Oligochaeta - 30- to 50-Foot Depth

The June 1974 density at the Inner stations was of the same magnitude as in October 1973 (average 390 and 340 per square foot, respectively) and lay within the projected Inner control limits. The Outer station densities had increased considerably in June 1974, averaging over 800 per square foot, and lay well outside the control limits for those stations. The densities in August 1974 (Figure C-50A) were low and lay within the control limits. Oligochaete densities were higher at both Inner and Outer stations at the 30- to 50-foot depth range in October 1973 (Figure C-55A) and lay well outside the control limits. Since biomass had not been shown to increase at the stations in the 20- to 30-foot depth range, this parameter was not investigated for the 30- to 50-foot stations. No individual oligochaete species showed a significant increase at any of the stations in this depth range. (See the Mann-Whitney section.)

Sphaeriidae - 20- to 30-Foot Depth

The densities of sphaeriids were low at stations which lay south of the discharge at depths between 20 and 30 feet. The 1973 August (Figure C-65A) result lay outside the control limits. In both 1974 surveys, June (Figure C-60A) and August results lay within the control limits, and showed small increases in density over those of previous years.

The charts were examined to see whether a general trend in organism density could be seen at any of the depths, but only three indicated such a change. There were steady decreases in density for amphipods in May at both

Inner and Outer stations south of the discharge at depths of 20 to 30 feet (Figure C-2A). The month of October had a similar decrease in density for sphaeriids at stations north of the discharge at the same depths, but a reversal occurred in 1973 (Figure C-69A). A similar decrease occurred for amphipods at 30- to 50-foot depths (Figure C-17A) with the trend halted in 1973. The density that year hardly changed from the level in 1972.

Sphaeriidae - 30- to 50-Foot Depth

Densities of sphaeriids at the 30- to 50-foot depths were significantly lower at the Inner stations for October 1972 and 1973 (Figure C-70A). In June, the 1973 result also lay outside the control limits with an average of 12 per square foot (Figure C-62A). In June 1974, there was a large increase at the Inner stations and the average density was 92 per square foot. Examination of all the samples showed that very small-sized sphaeriids were present in high numbers in most of the samples, indicating an initial breeding success. The density increases occurred at both C-1 and F-1 (Inner) and at H-2 (Outer). The other Outer station densities were low, but still contained a high proportion of young individuals. By August 1974 (Figure C-66A), the Inner average density had decreased to 38 per square foot and lay within the control limits, very close to the October density levels (45 per square foot). The organic carbon composition of the sediments was checked to see if this could have had an effect on the sphaeriids by creating a larger food supply, but the percent organic carbon remained constant at C-1 and H-2 in 1971 and 1973 with a decrease at F-1 in 1973; thus, the sphaeriid densities could not be correlated with changes in this parameter.

Ayers and Seibel(1) discussed the seasonal changes which occurred for some of the more common organisms throughout the year. These compared well with the fluctuations in density found during the year in the Palisades samples. Amphipods were most numerous in June at the shallower stations, and in August and October at the deeper stations in the vicinity of Palisades, while they were most numerous in July and September at the Cook Plant. Oligochaetes were most numerous in August and October at Palisades and in September and November at Cook. The June, August and October samples contained very similar numbers of chironomids at the shallower Palisades stations, but the densities at the deepest group of stations fluctuated more and corresponded with the Cook samples which contained the most chironomids in July, while Palisades samples contained the highest numbers in August.

Control Charts for Benthic Community Diversity

Diversity indices were calculated for the three June control charts which incorporated the stations with depths ranging between 20 and 50 feet. None of the indices fell within the control limits of the charts.

The diversity index at stations lying north of the discharge at depths between 20 and 30 feet (Figure C-73A) fluctuated at both Inner and Outer stations between 1968 and 1971, then increased steadily at the Inner stations.

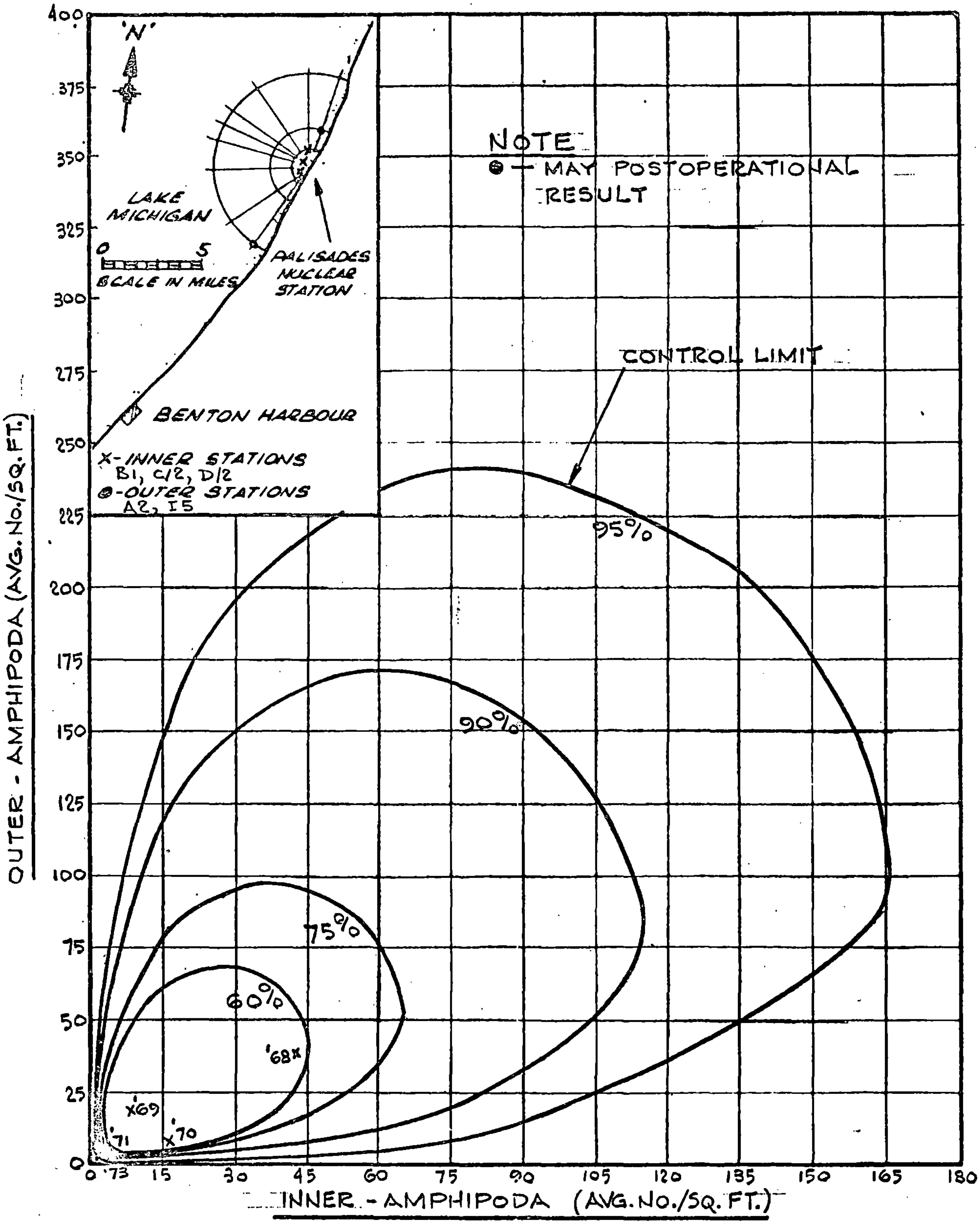
The diversity decreased at the Outer stations between 1971 and 1974 with a similar diversity present in 1972 and 1973. The Inner 1974 diversity changed very little in 1974 from that of 1973 and was similar to the 1968 diversity, but the Outer average diversity was the lowest recorded for the seven years. The two Outer stations involved in this chart, A-2 and 1-5, were two of the stations where more than the average (4 and 5, respectively) number of significant decreases in density occurred in the postoperational period.

Stations at the same depth but lying south of the discharge (Figure C-74A) had the June 1974 diversity lying well outside the control limits, the position being caused by decreases at both Inner and Outer stations.

The diversity at the Inner 30- to 50-foot stations was very similar to 1972 and 1973 (Figure C-75A). The point lay outside the control limits but very little change had occurred since 1972. The biggest change occurred at the Outer stations when, as in the 20- to 30-foot north quadrant, the 1974 diversity was the lowest that had been recorded in the seven years.

REFERENCES

Ayers, John C. and Erwin Seibel, 1973. Benton Harbor Power Plant limnological studies, Part XIII. Cook Plant preoperational studies, 1972. Great Lakes Research Division, University of Michigan Special Report No 44.



DENSITY OF SCUDS - NORTH QUADRANT - DEPTH 20-30 FT.

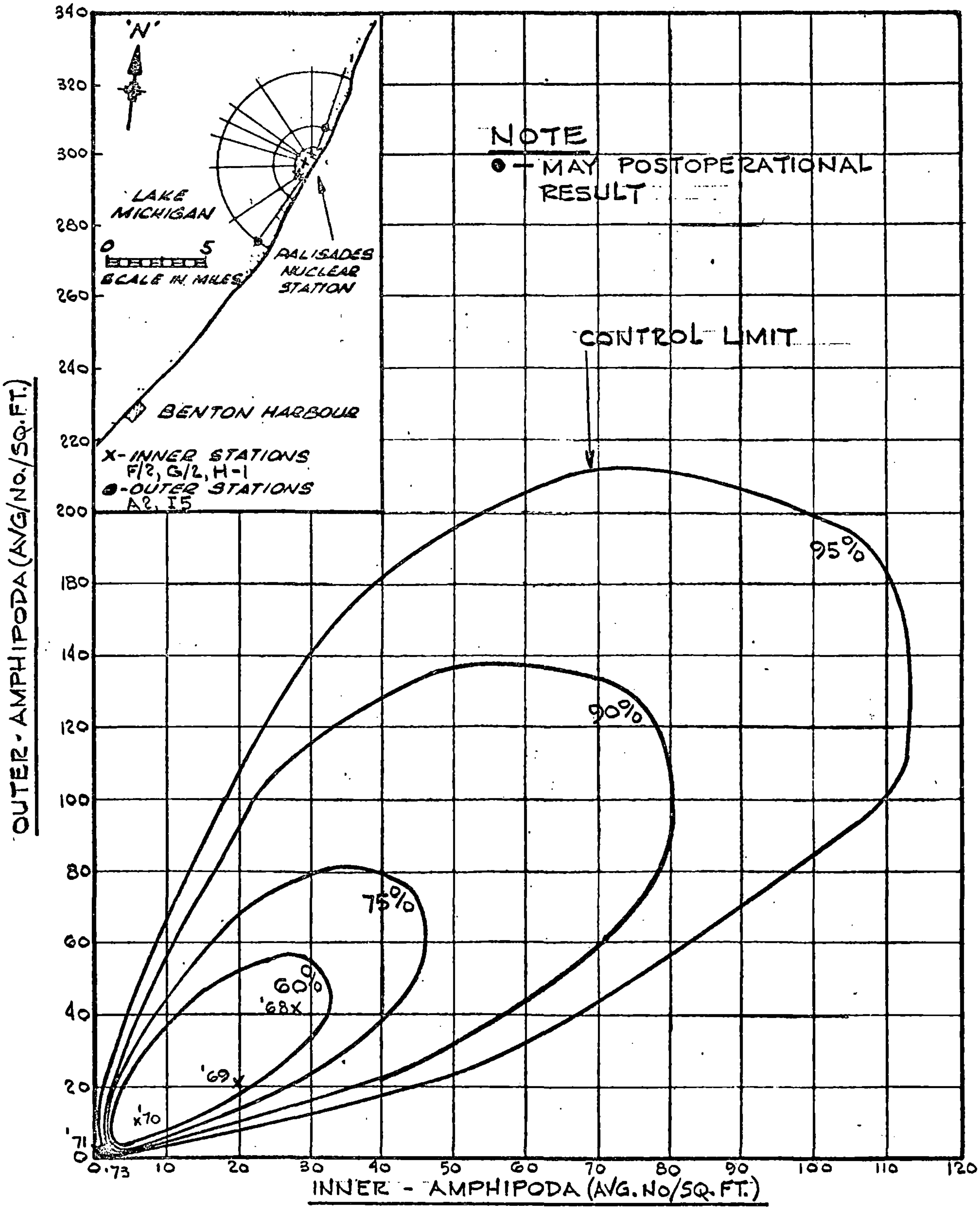
MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO A2048-64	*FIG.* C-1A

TRANSLAR 003



DENSITY OF SCUDS - SOUTH QUADRANT - DEPTH 20-30FT.

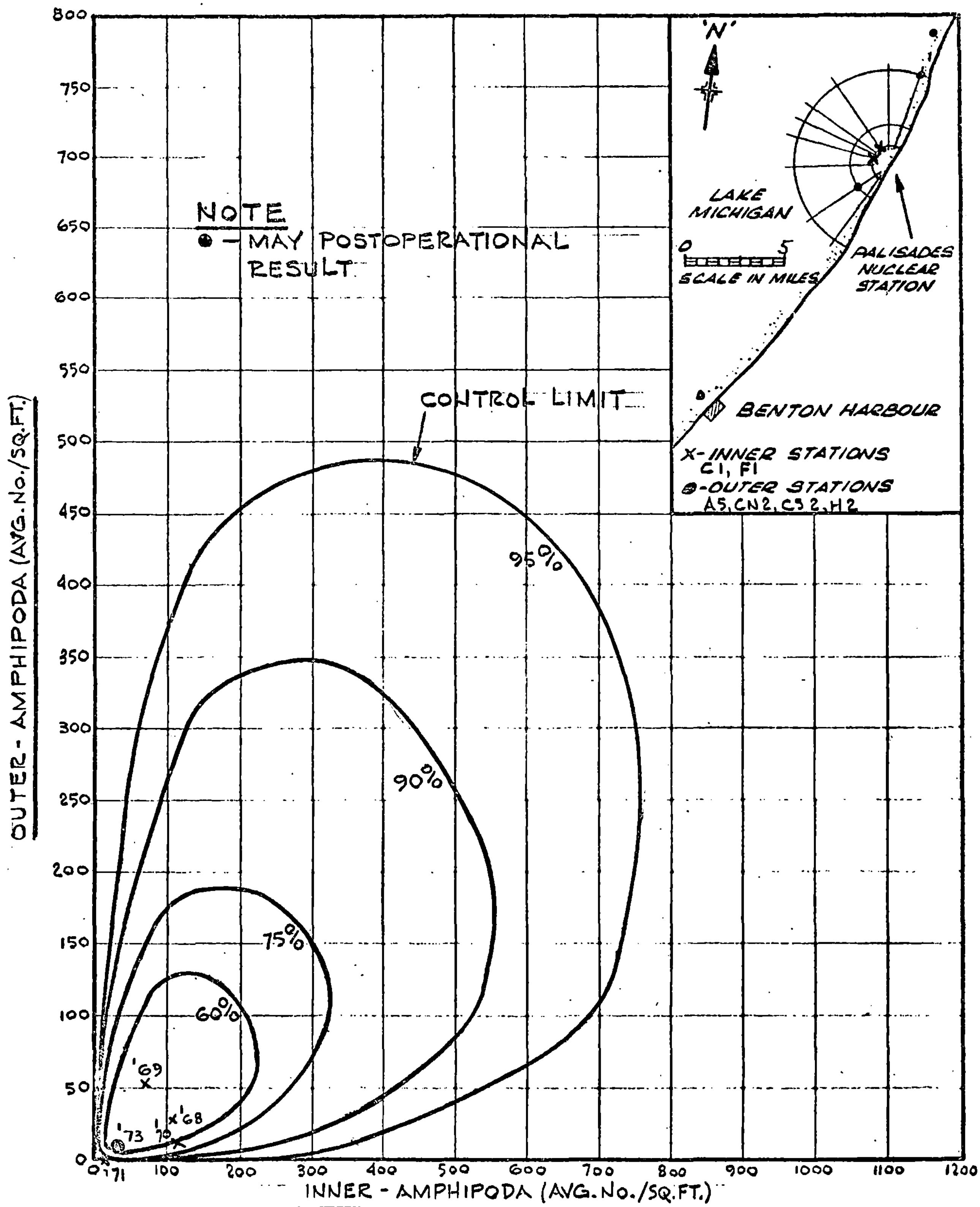
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	8.2 BEAK	BY DATE 17-10-73 DWG NO A2048-65	FIG. C-2A

TRANSLAR 003



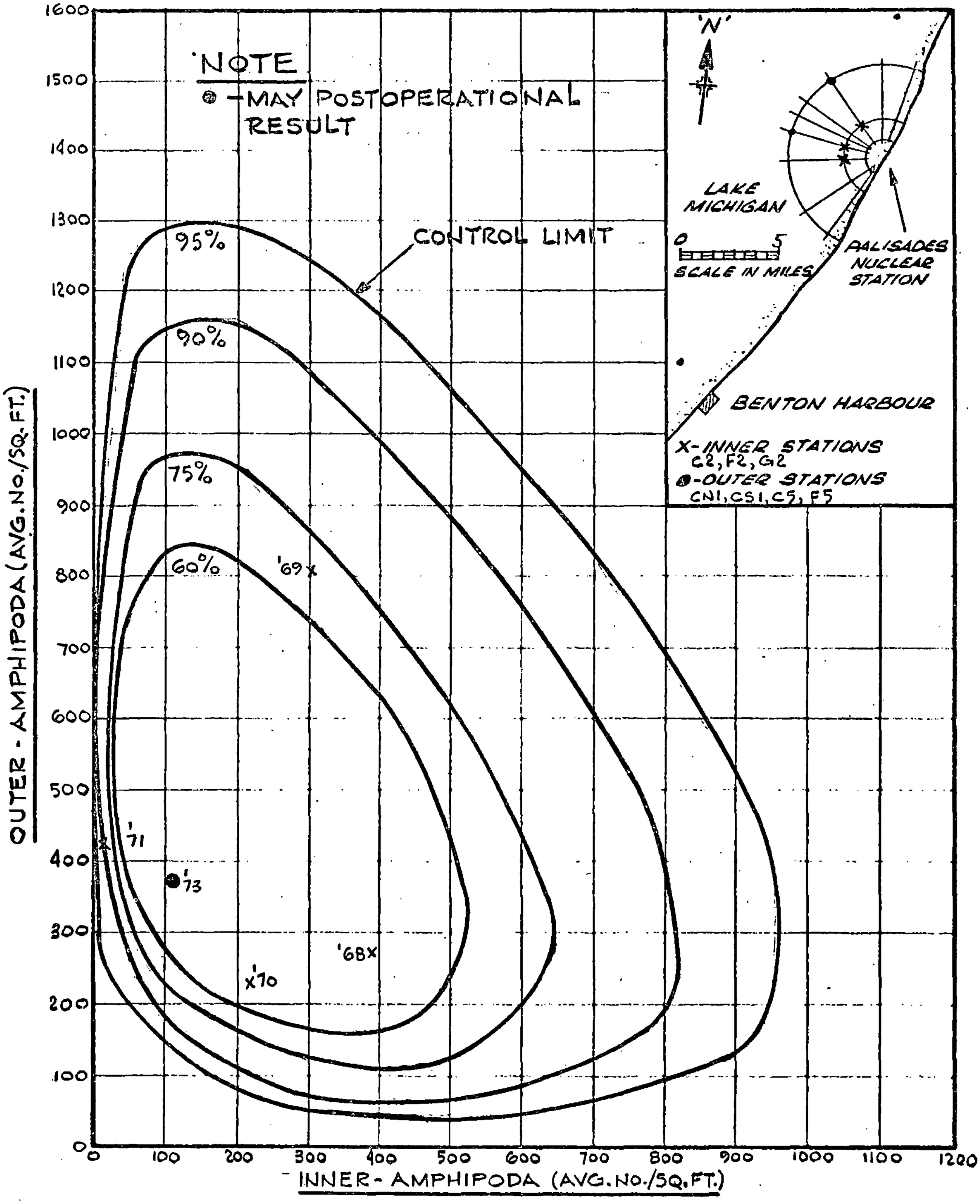
DENSITY OF SCUDS - DEPTH 30 - 50 FT.

MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO A 2048 - 66	*FIG.* C-3A



DENSITY OF SCUDS - DEPTHS GREATER THAN 50 FT.

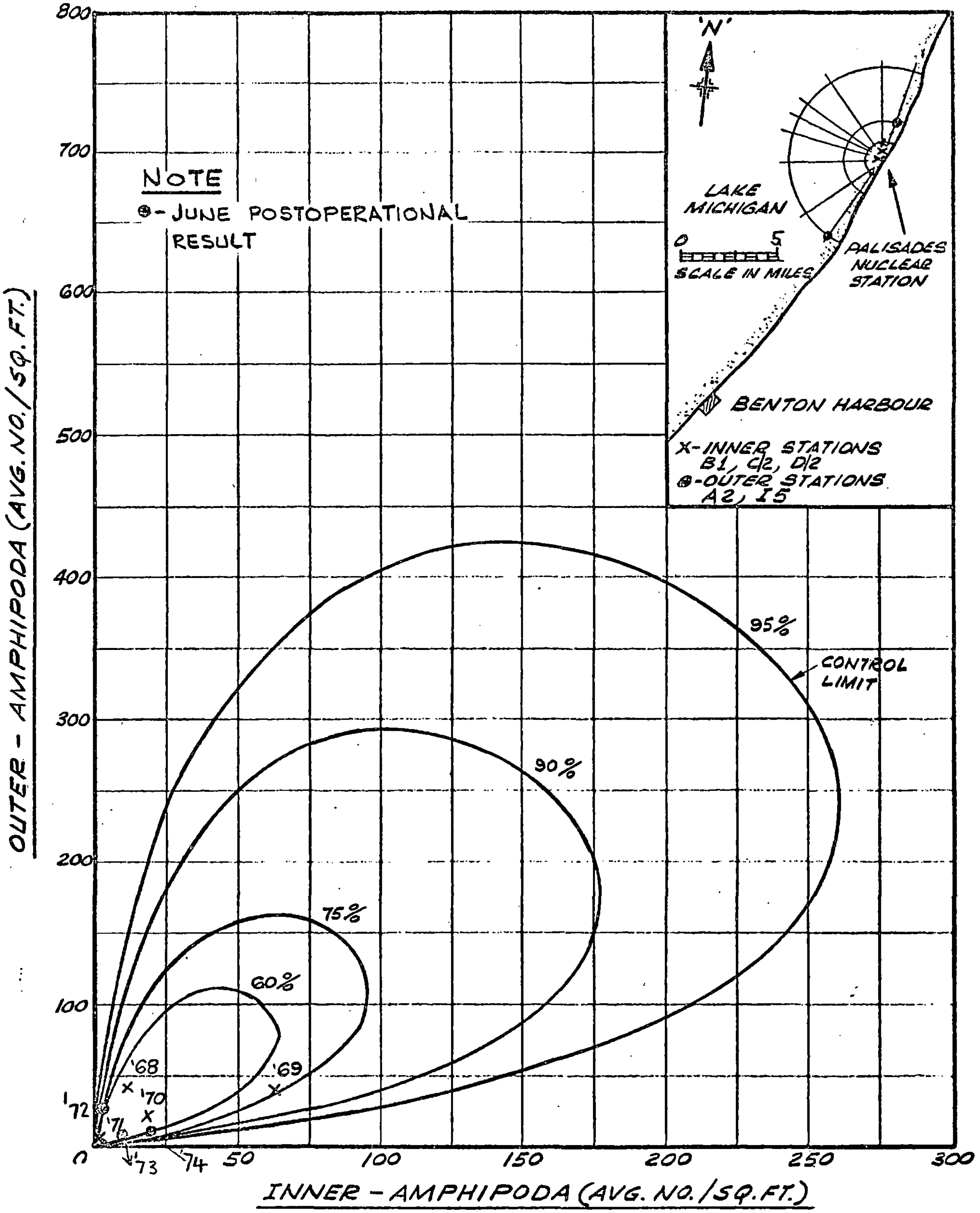
MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO A 2048 - 67	*FIG.* C-4A

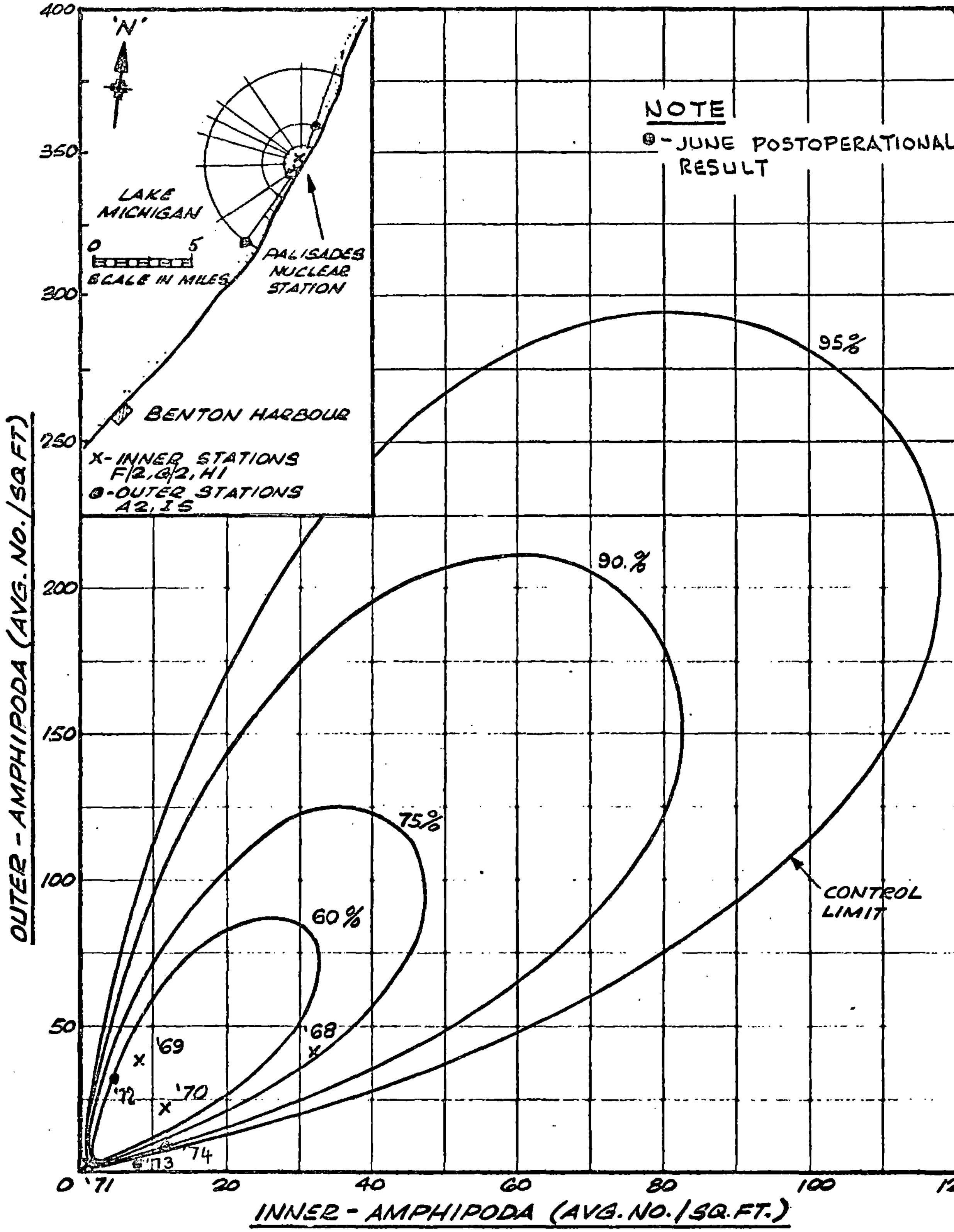
TRANSLAR 003



DENSITY OF SCUDS-NORTH QUADRANT-DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	4.6 BEAK	BY S.R. DATE 13 1.75 DWG NO A 2048 - 11	FIG. C-5A

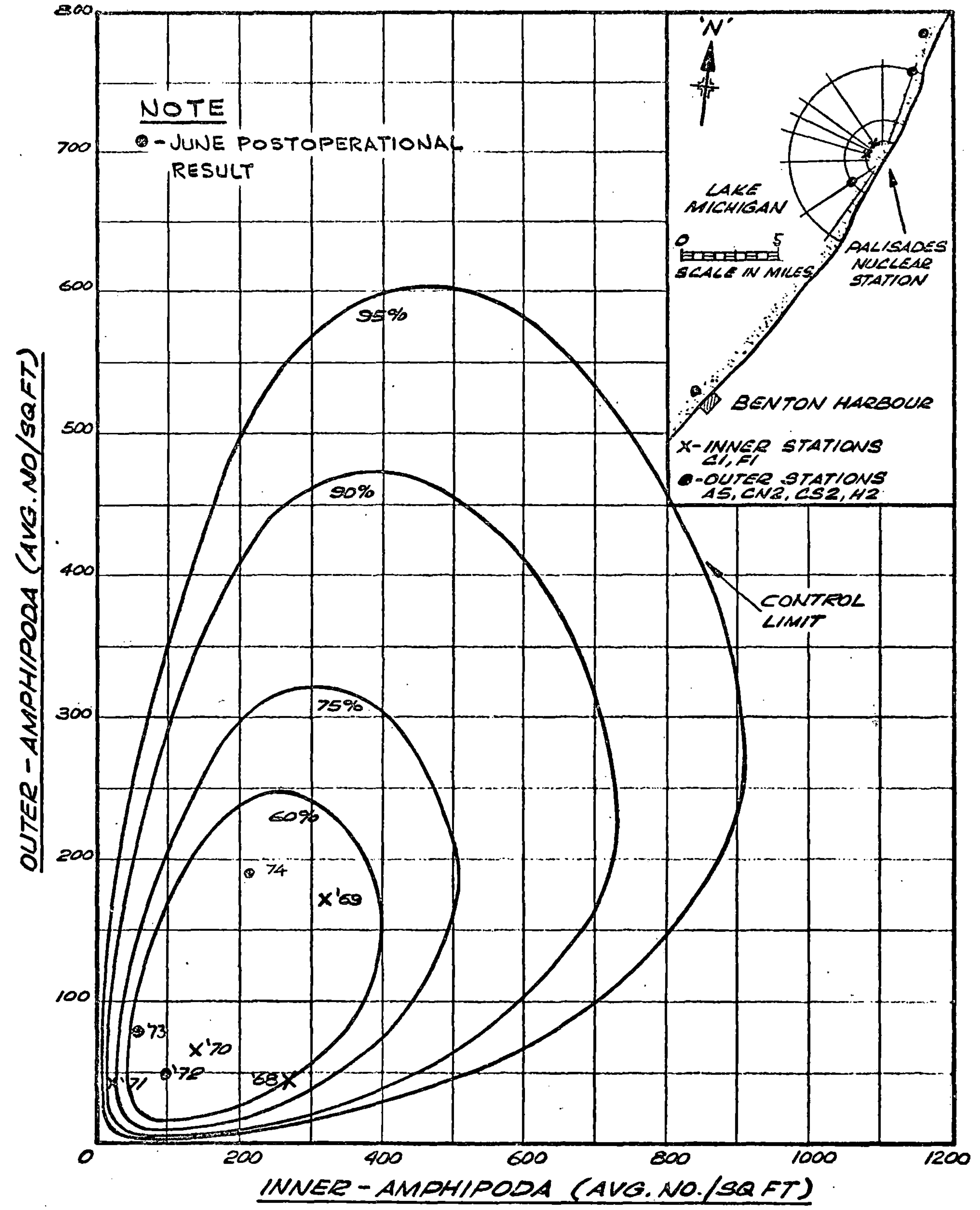
TRANSLAR 003



DENSITY OF SCUDS - SOUTH QUADRANT - DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 4-7	BY RCD DATE 13-1-75 DWG NO A 2048 - 12	FIG. 1C-6A

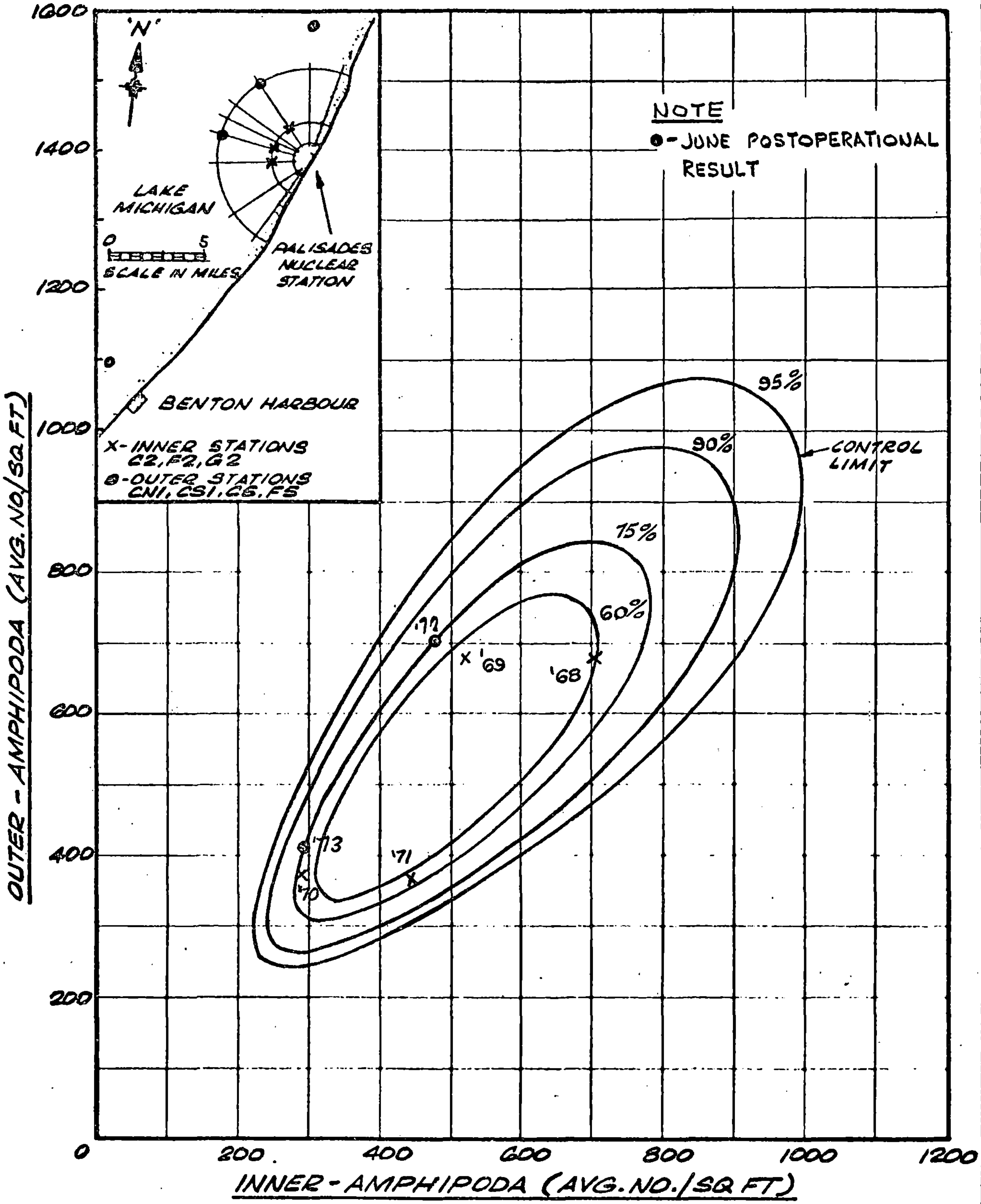
TRANSLAR 003



DENSITY OF SCUDS - DEPTH 30-50 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	4.8 BEAK	BY RCD DATE 3·1·75 DWG NO A 2048 - 13	FIG. C-7A

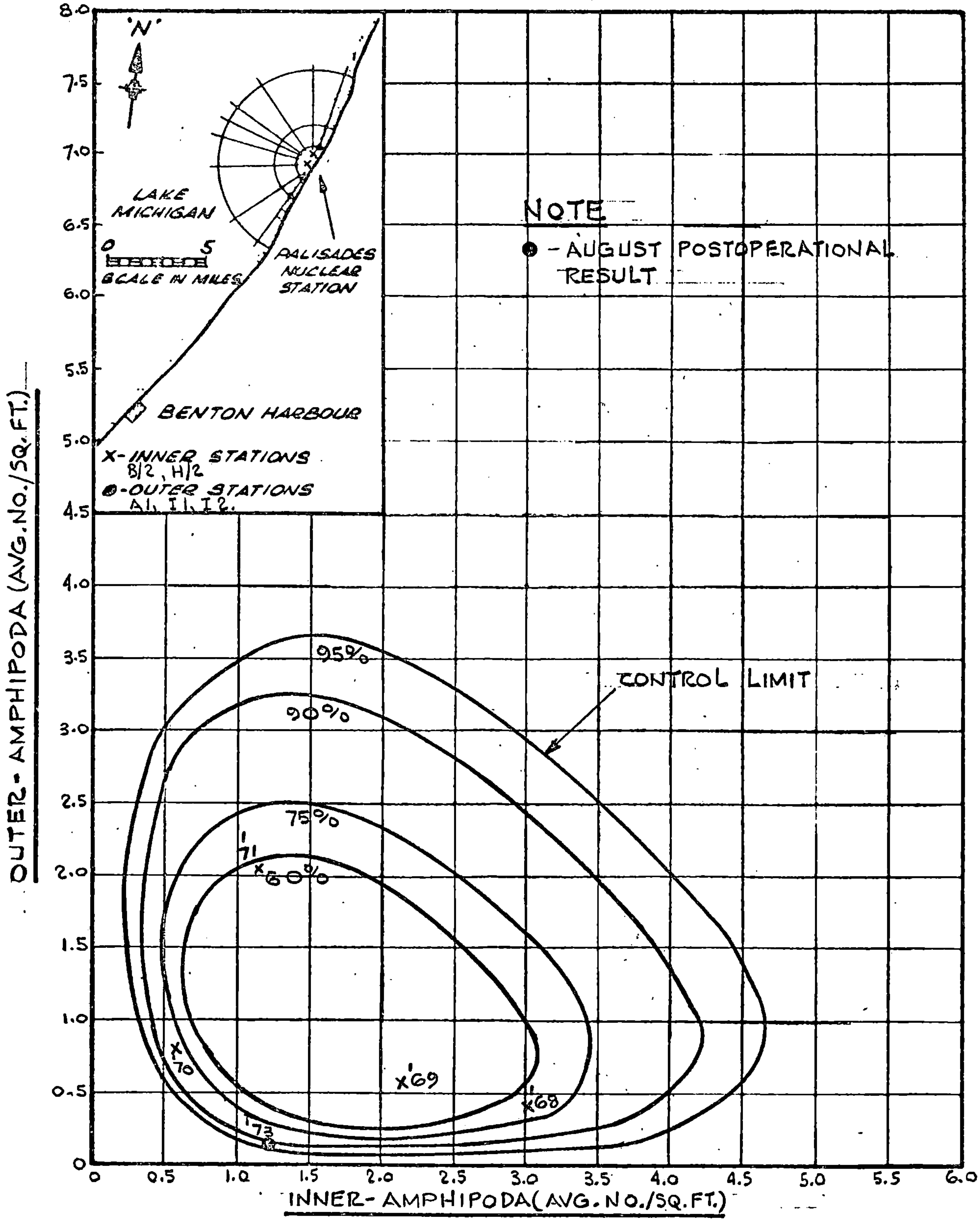
TRANSLAR 003



DENSITY OF SCUDS - DEPTH GREATER THAN 50 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 15/73 DWG NO A 2048 - 14	FIG. C-8A

TRANSLAR 003



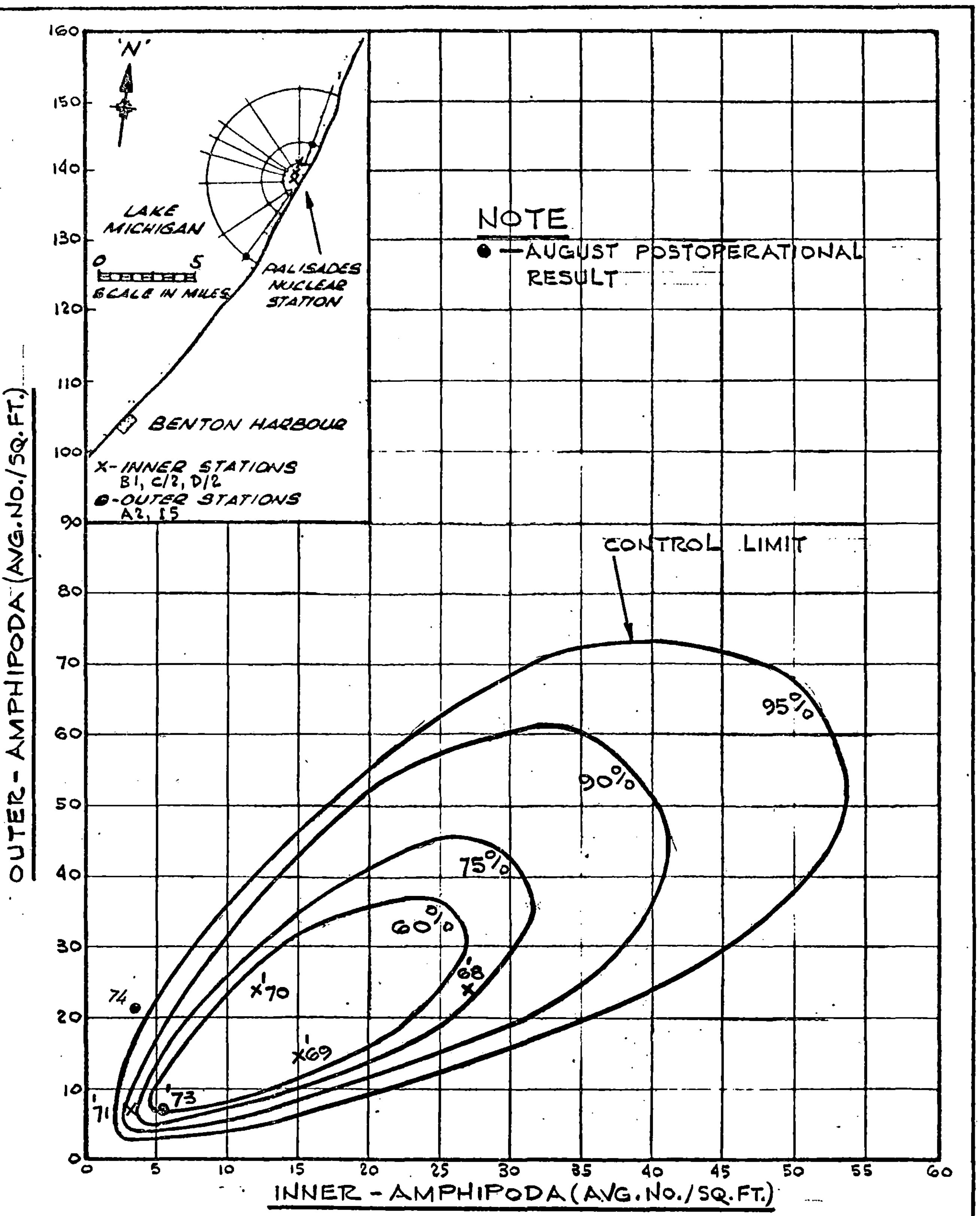
DENSITY OF SCUDS - DEPTH LESS THAN 20 FT.

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY / DATE 17-10-73 DWG NO A 2048 - 82	FIG. C-9A



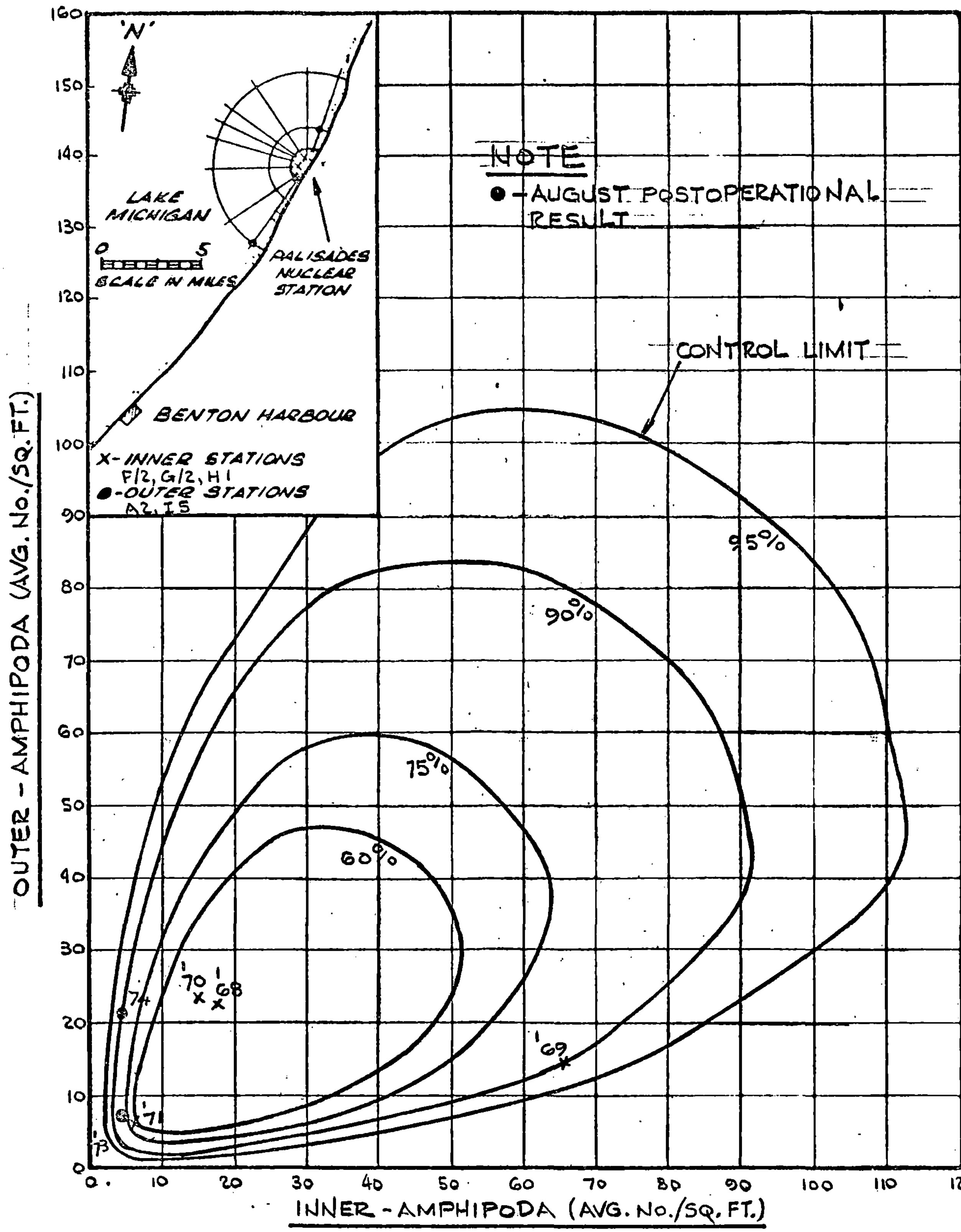
DENSITY OF SCUDS - NORTH QUADRANT - DEPTH 20-30FT.

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK 9.2	BY DATE 13·1·75 DWG NO A 2048 - 83	FIG. C-10A



DENSITY OF SCUDS - SOUTH QUADRANT - DEPTH 20-30 FT.

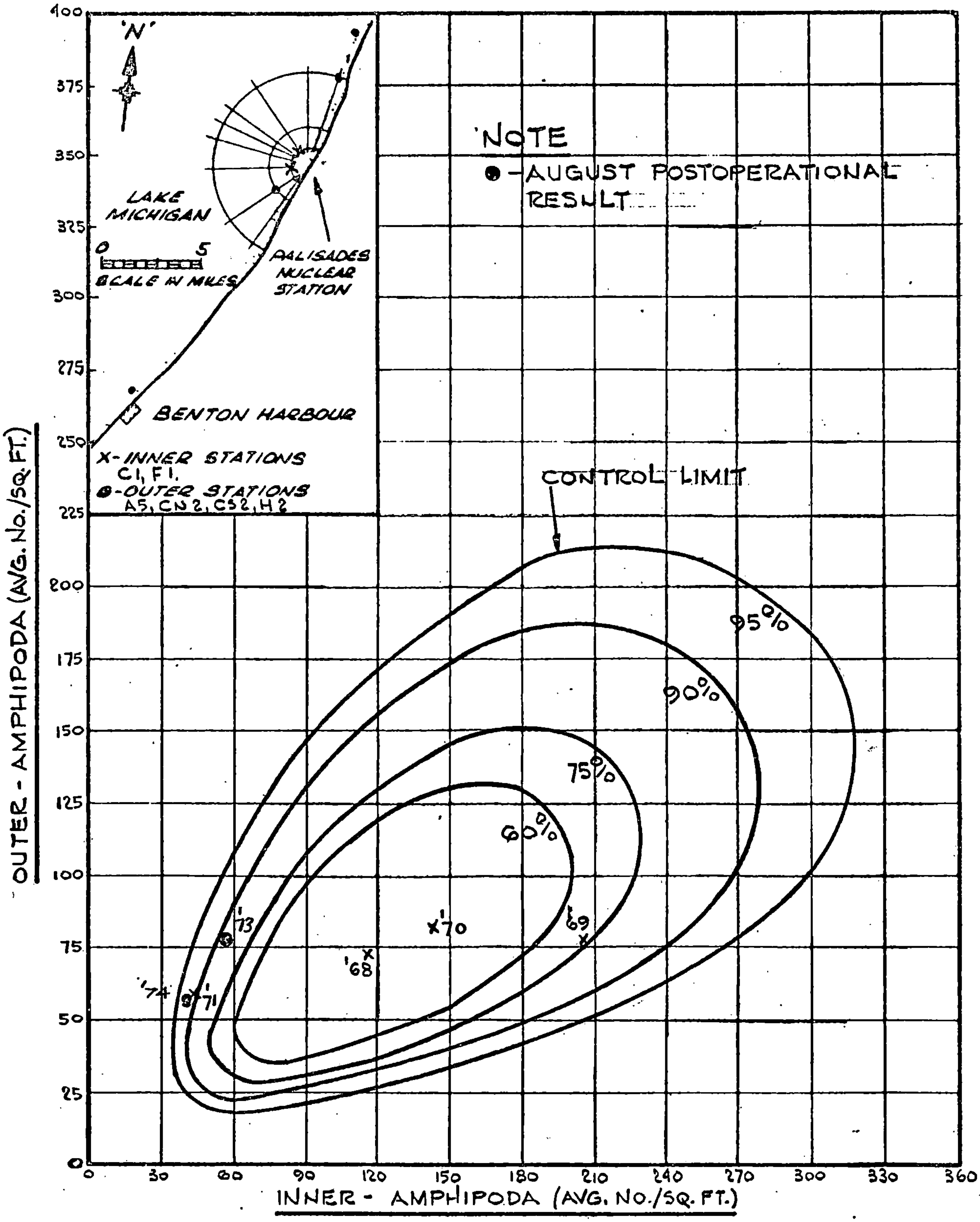
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	9.3 BEAK	BY DATE 13·1·75 DWG NO *A 2048-84*	*FIG.* C-11A

TRANSLAR 003



DENSITY OF SCUDS - DEPTH 30-50 FT.

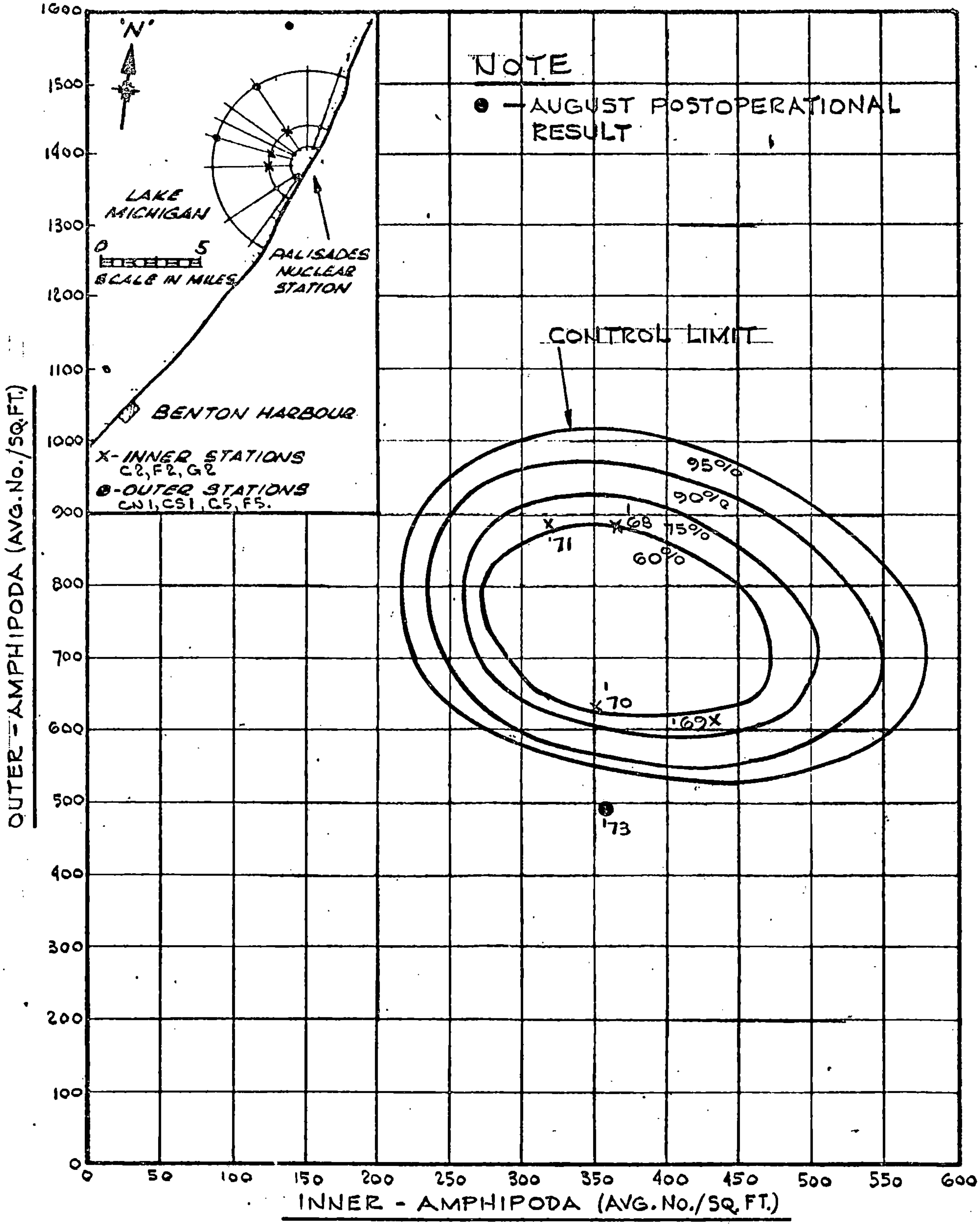
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK 9.4	BY DATE 17-10-73 DWG NO A 2048-85	*FIG.* C-12A

TRANSLAR 003



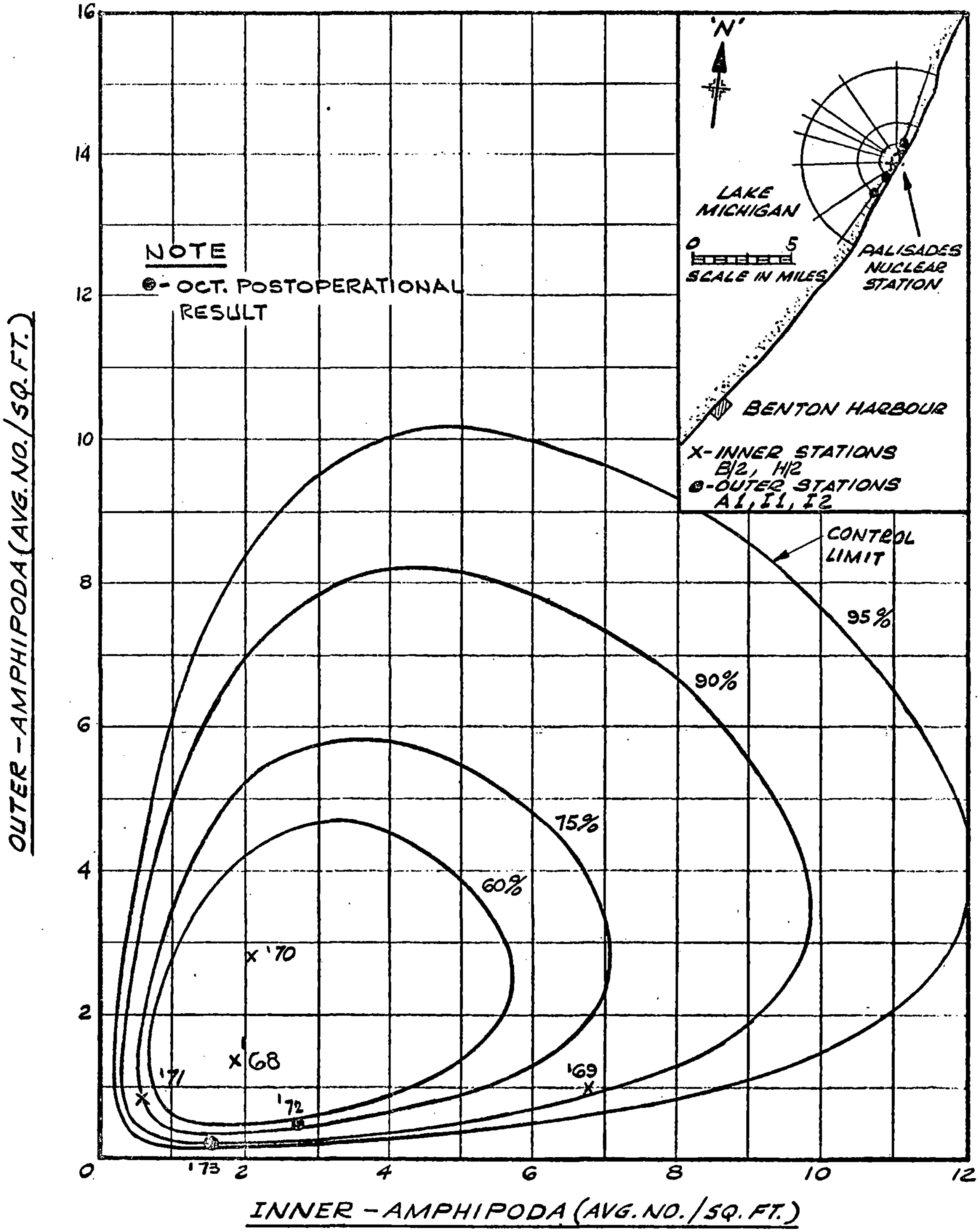
DENSITY OF SCUDS - DEPTH GREATER THAN 50FT

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

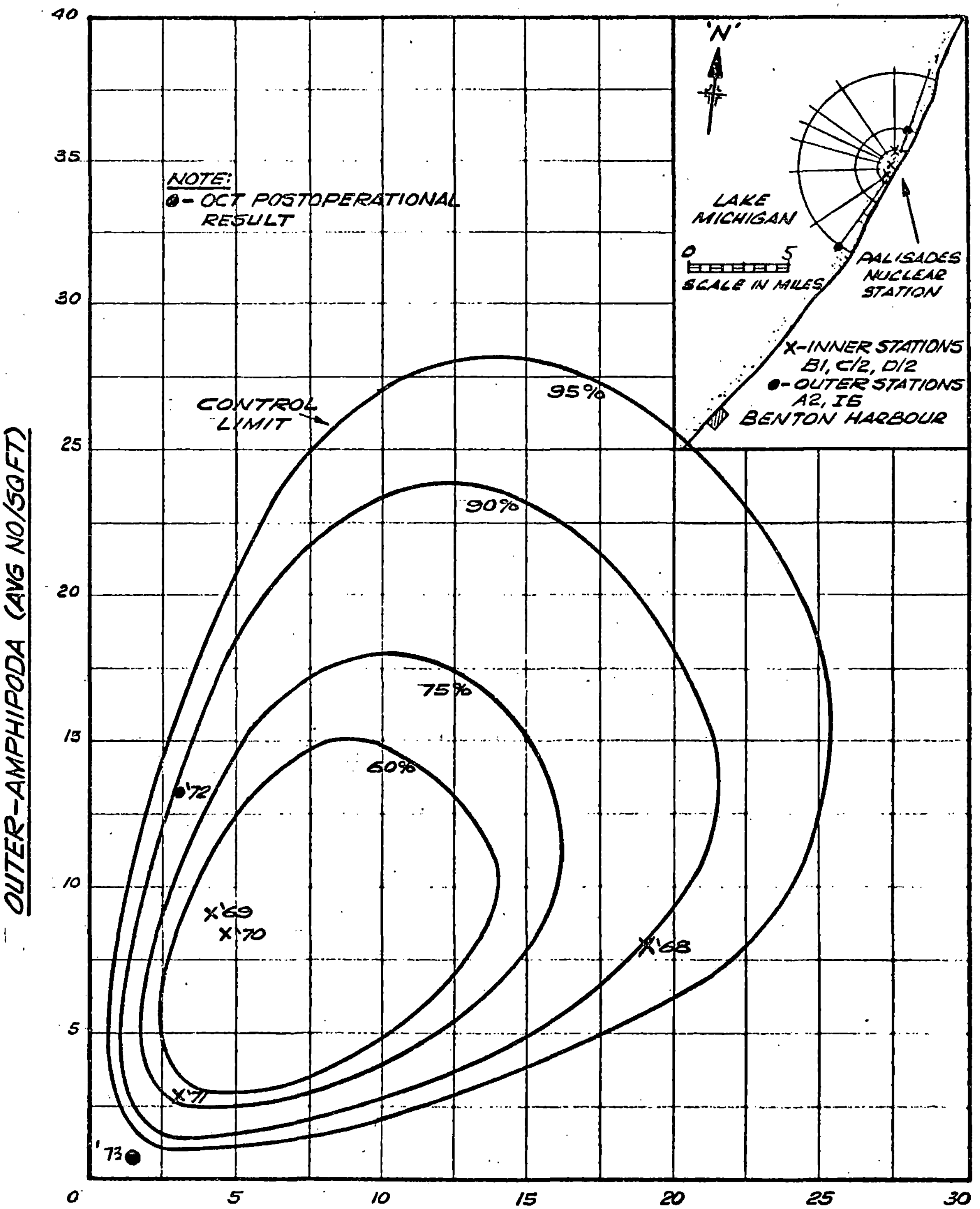
CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO A 2048-86	*FIG.* C-13A



DENSITY OF SCUDS - DEPTH LESS THAN 20 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY S. R.	DATE JAN 15/73	FIG. C-14A
		DWG NO A 2048 - 30		

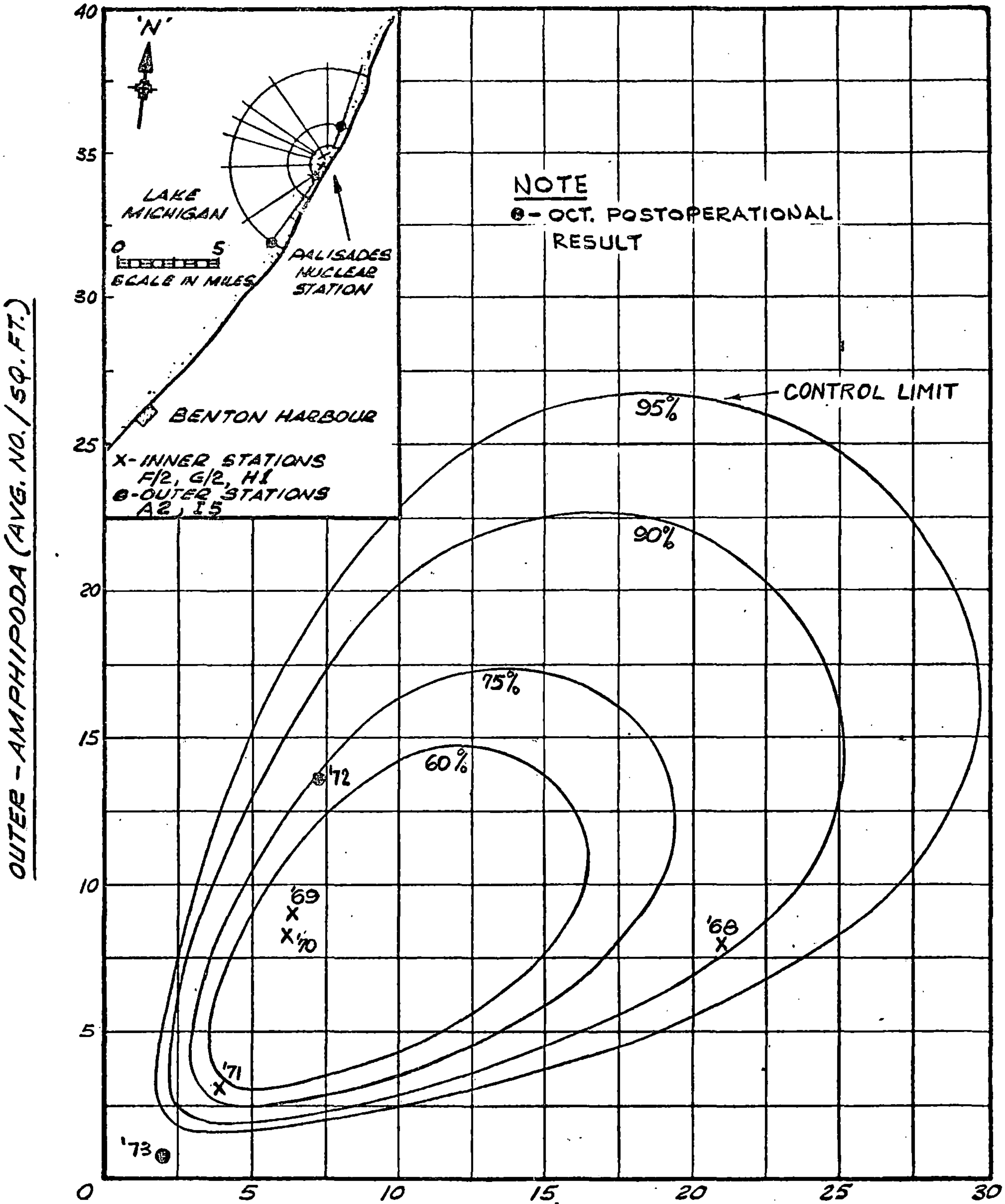
TRANSLAR 003



DENSITY OF SCUDS - NORTH QUADRANT - DEPTH 20-30FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

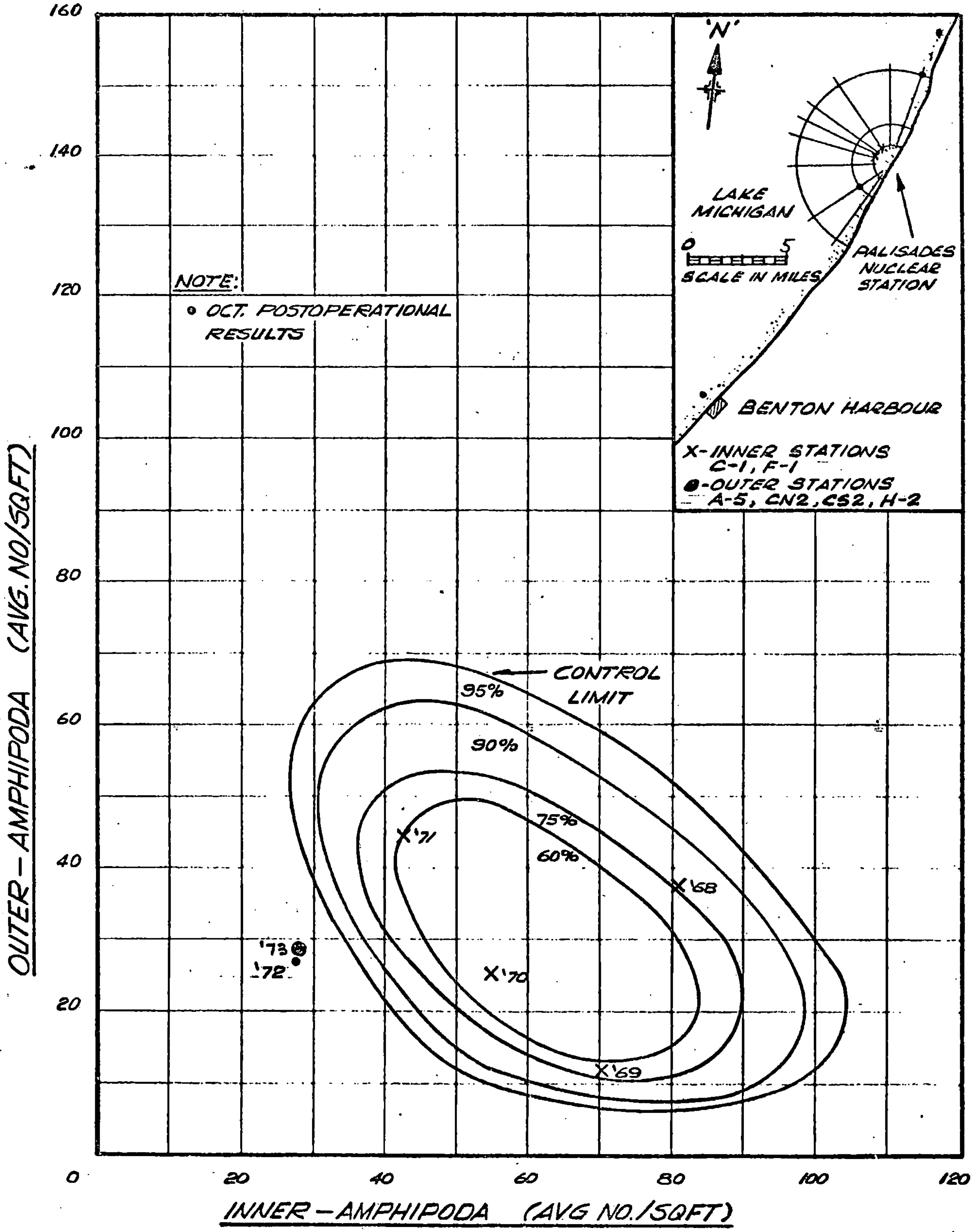
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 5.6	BY RAC	DATE 1 AUG 73	FIG. C-15A
		DWG NO A 2048-31		

TRANSLAR 003



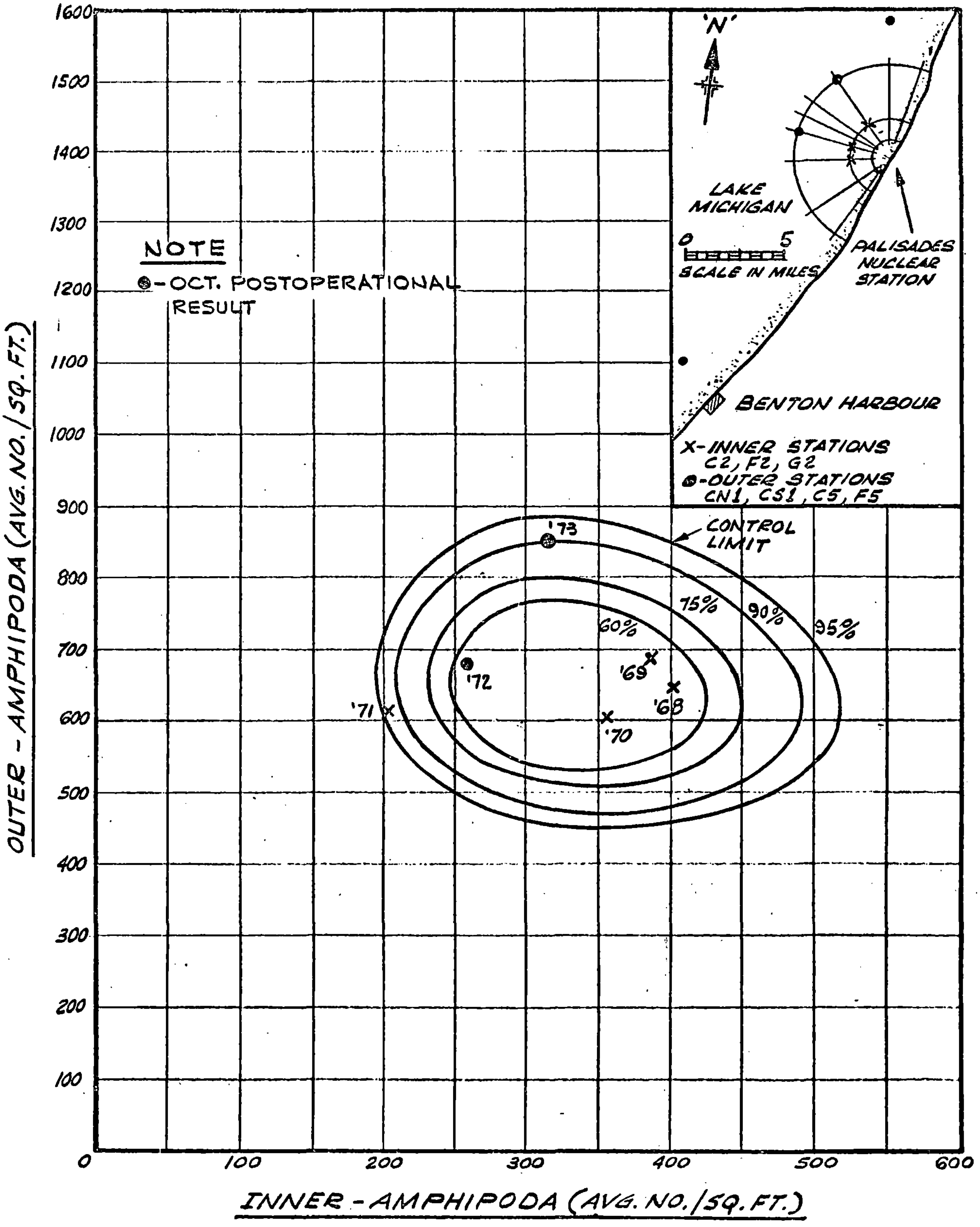
DENSITY OF SCUDS - SOUTH QUADRANT - DEPTH 20-30 FT.
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK S-7	BY S.R. DATE JAN 15/73 DWG NO A 2048-32	FIG. C-16A



DENSITY OF SCUDS — DEPTH 30-50 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	5.8 BEAK	BY PAC	DATE 1 AUG '73	FIG. C-17A
		DWG NO A 2048 - 33		



DENSITY OF SCUDS - DEPTH GREATER THAN 50FT

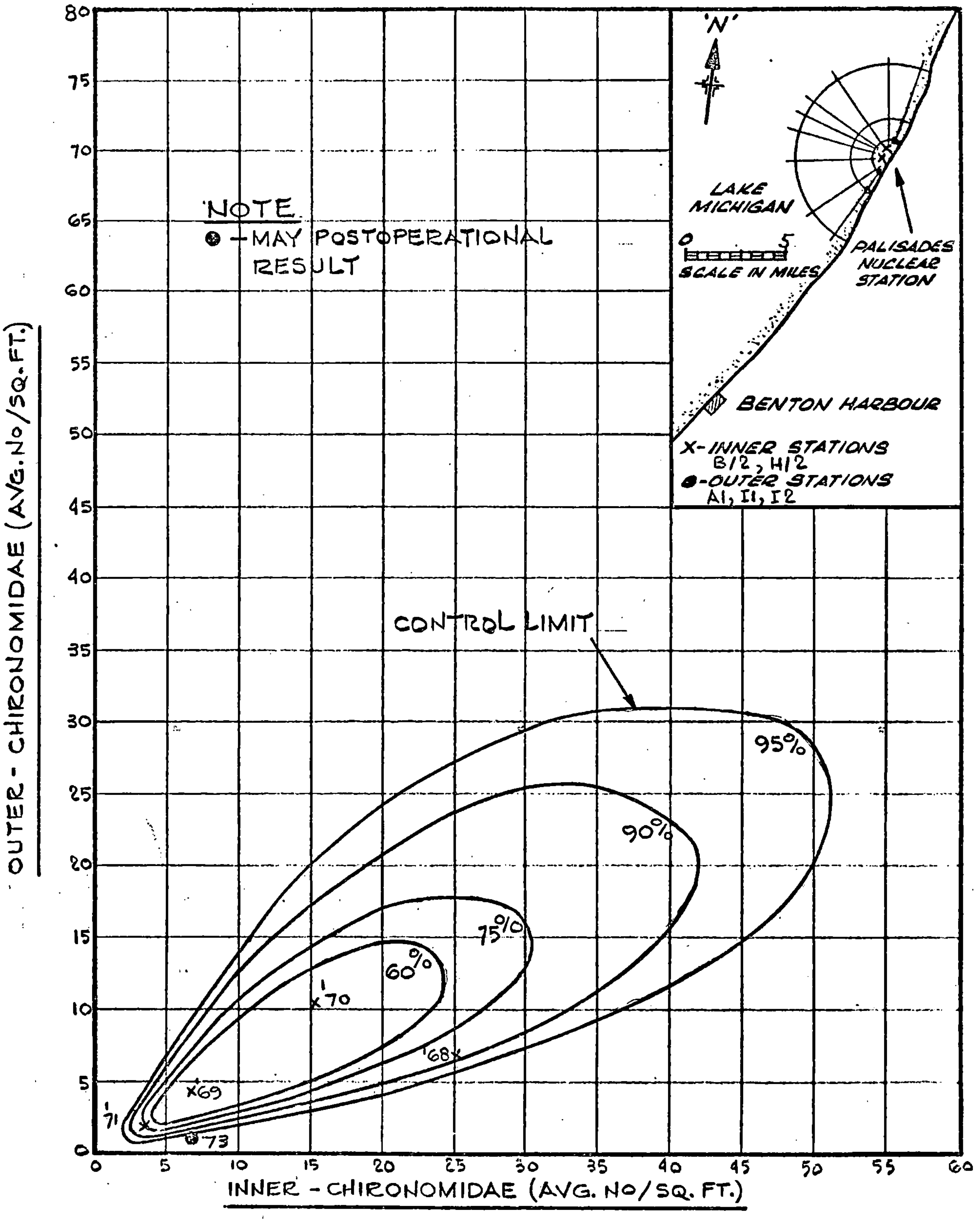
OCTOBER BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY S. R. DATE JAN 15/73 DWG NO A 2048 - 34	FIG. C-18A

TRANSLAR 003



DENSITY OF MIDGES - DEPTH LESS THAN 20 FT.

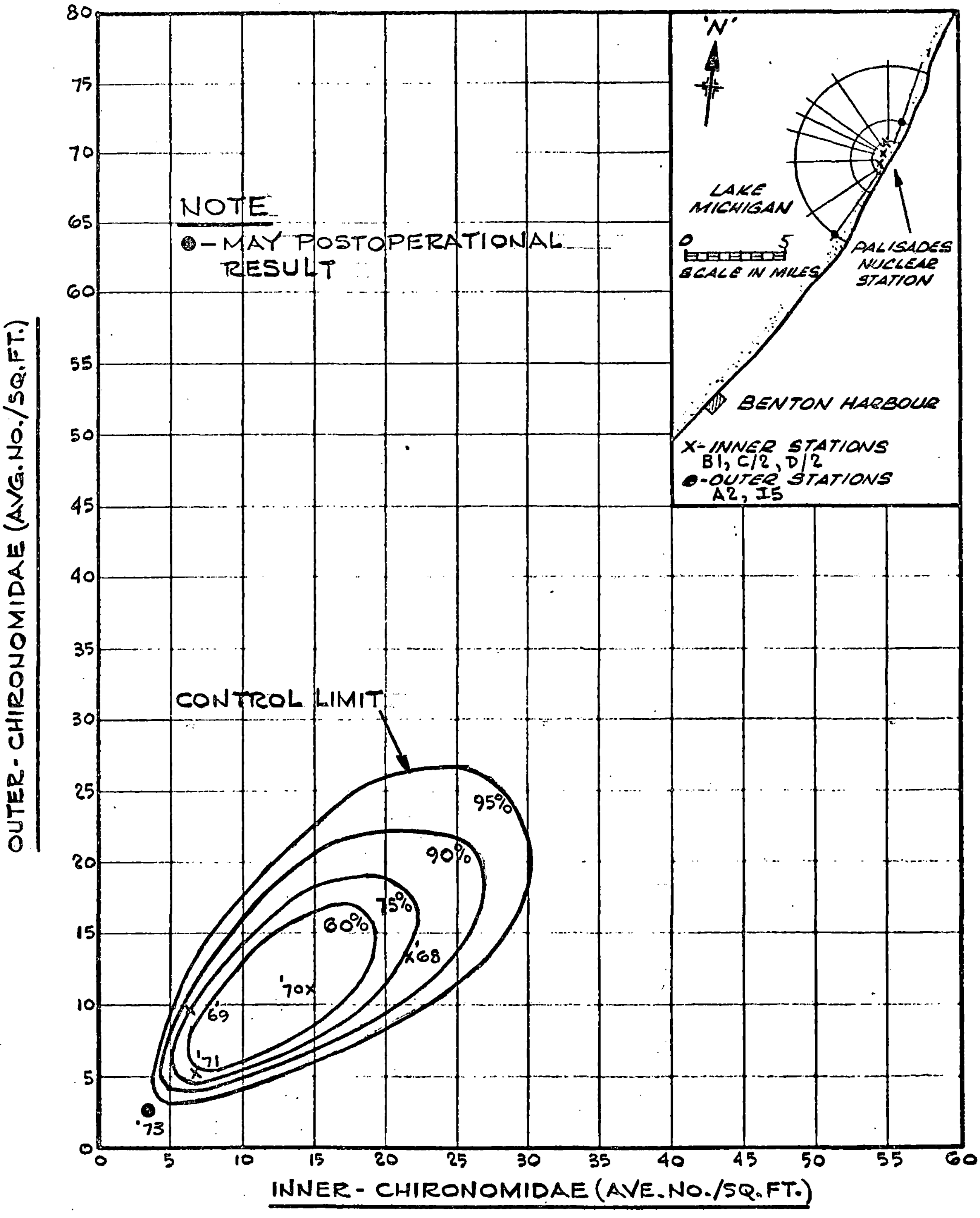
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY DWG NO A2048-68	DATE 17 10-73 FIG. C-19A

TRANSLAR 003



DENSITY OF MIDGES – NORTH QUADRANT – DEPTH 20-30 FT.

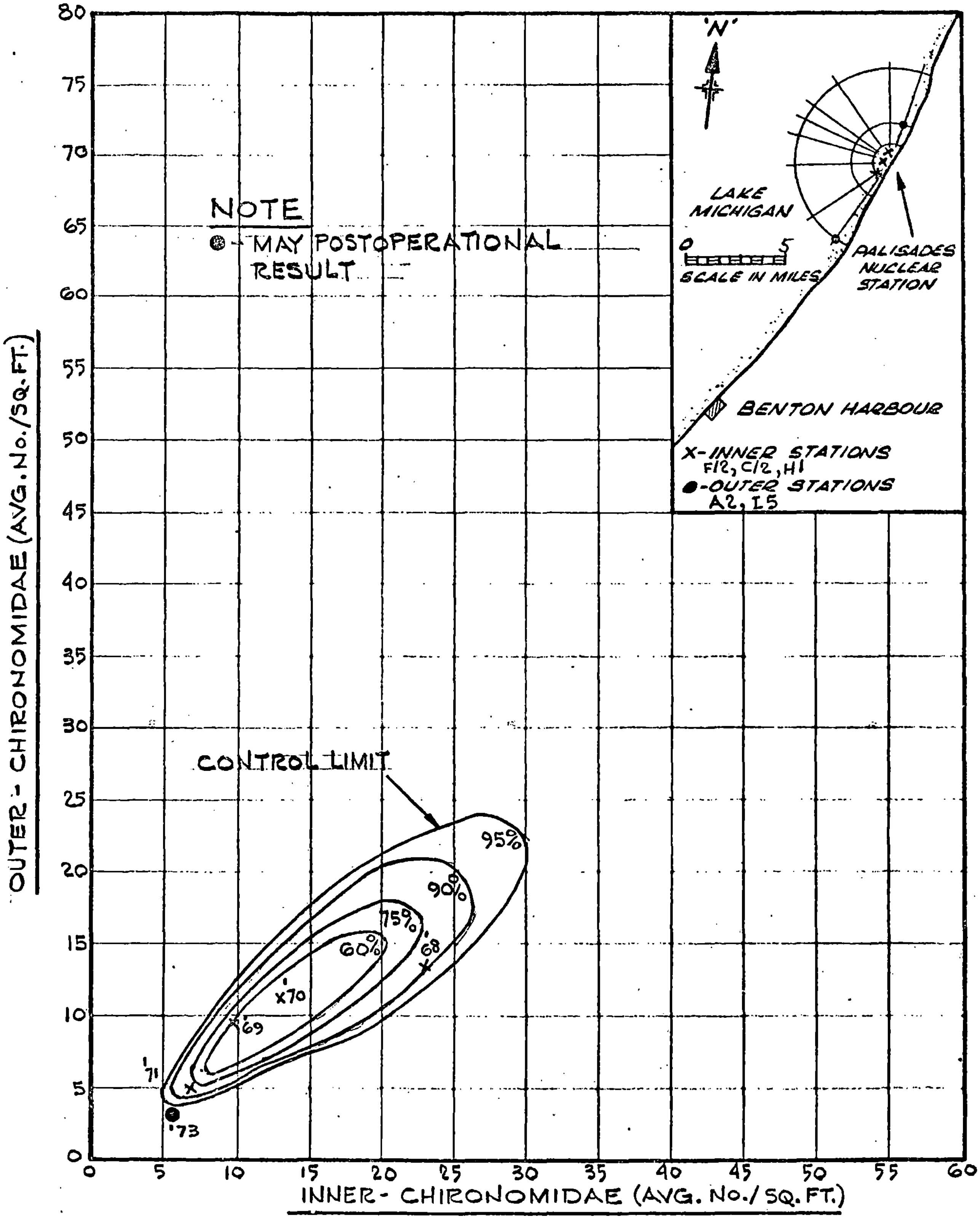
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON – MICHIGAN	BEAK	BY DWG NO A 2048 – 69	DATE 17-10-73	FIG. C-20A

TRANSLAR 003

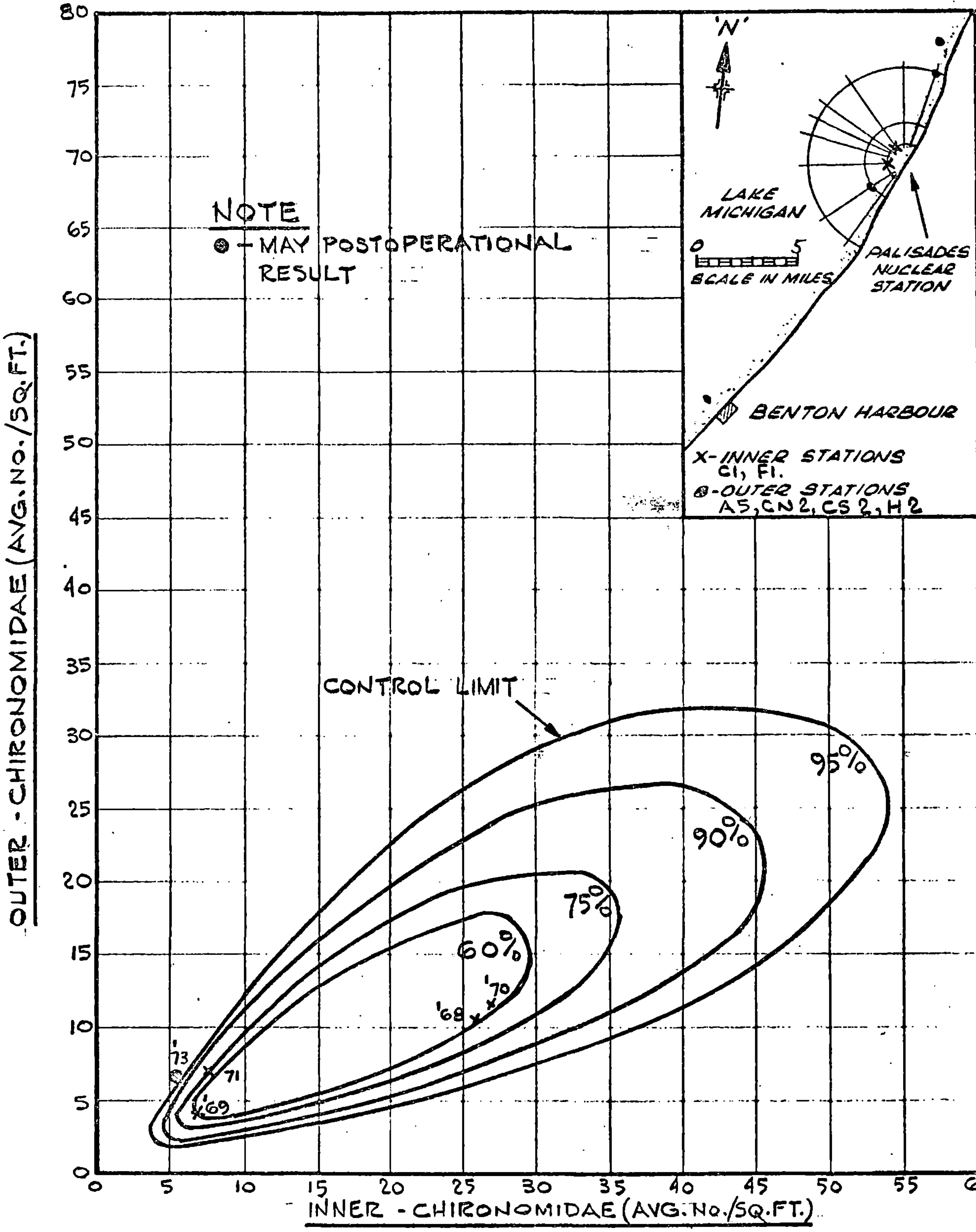


DENSITY OF MIDGES - SOUTH QUADRANT - DEPTH 20-30 FT.

MAY BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY DATE 17-10-73 DWG NO A2048-70	FIG. C-21A

TRANSLAR 003



DENSITY OF MIDGES - DEPTH 30 - 50FT.

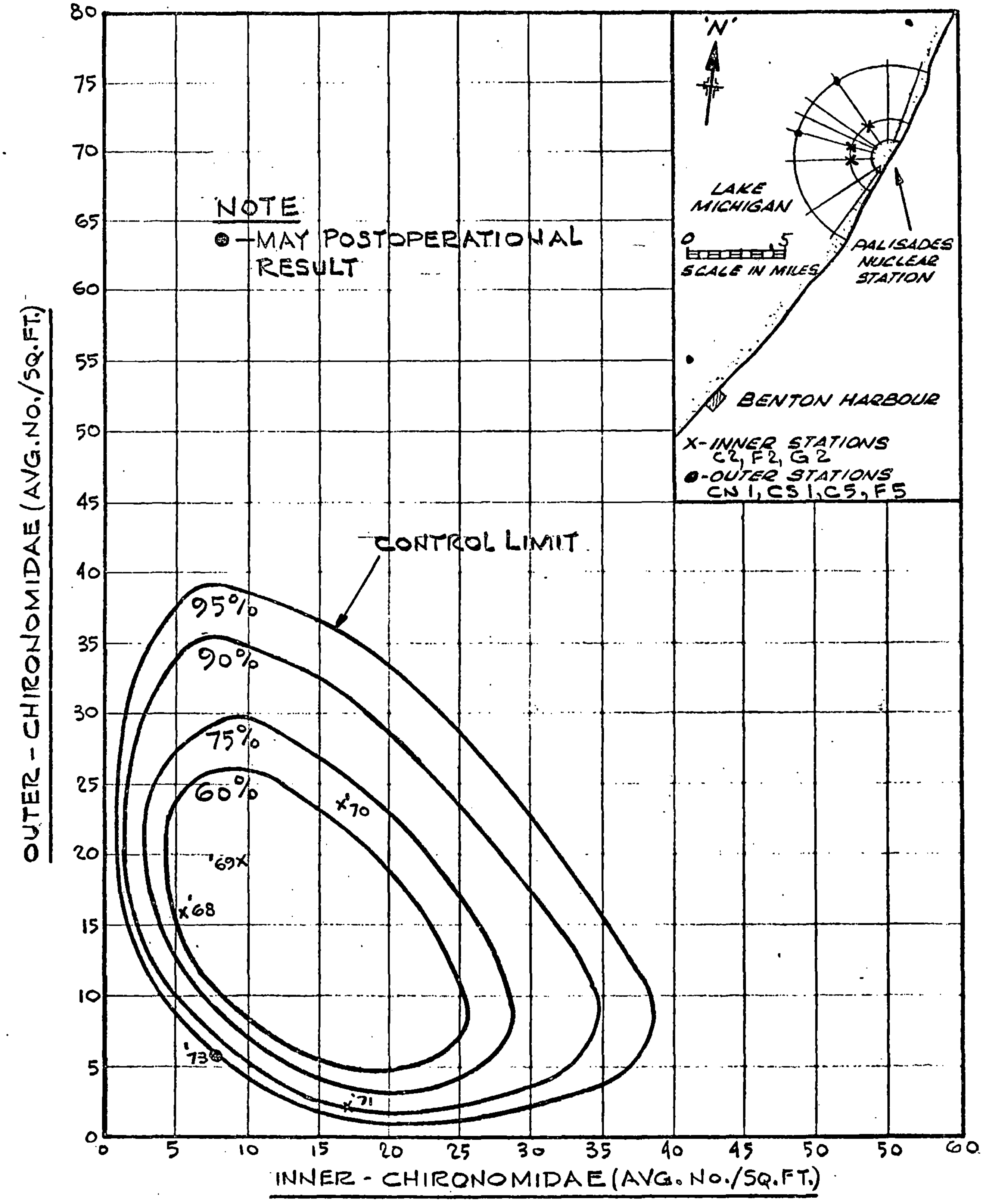
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY DATE 17-10-73 DWG NO A 2048 - 71	FIG. C-22A

TRANSLAR 003



MIDGE DENSITY – DEPTH GREATER THAN 50 FT.

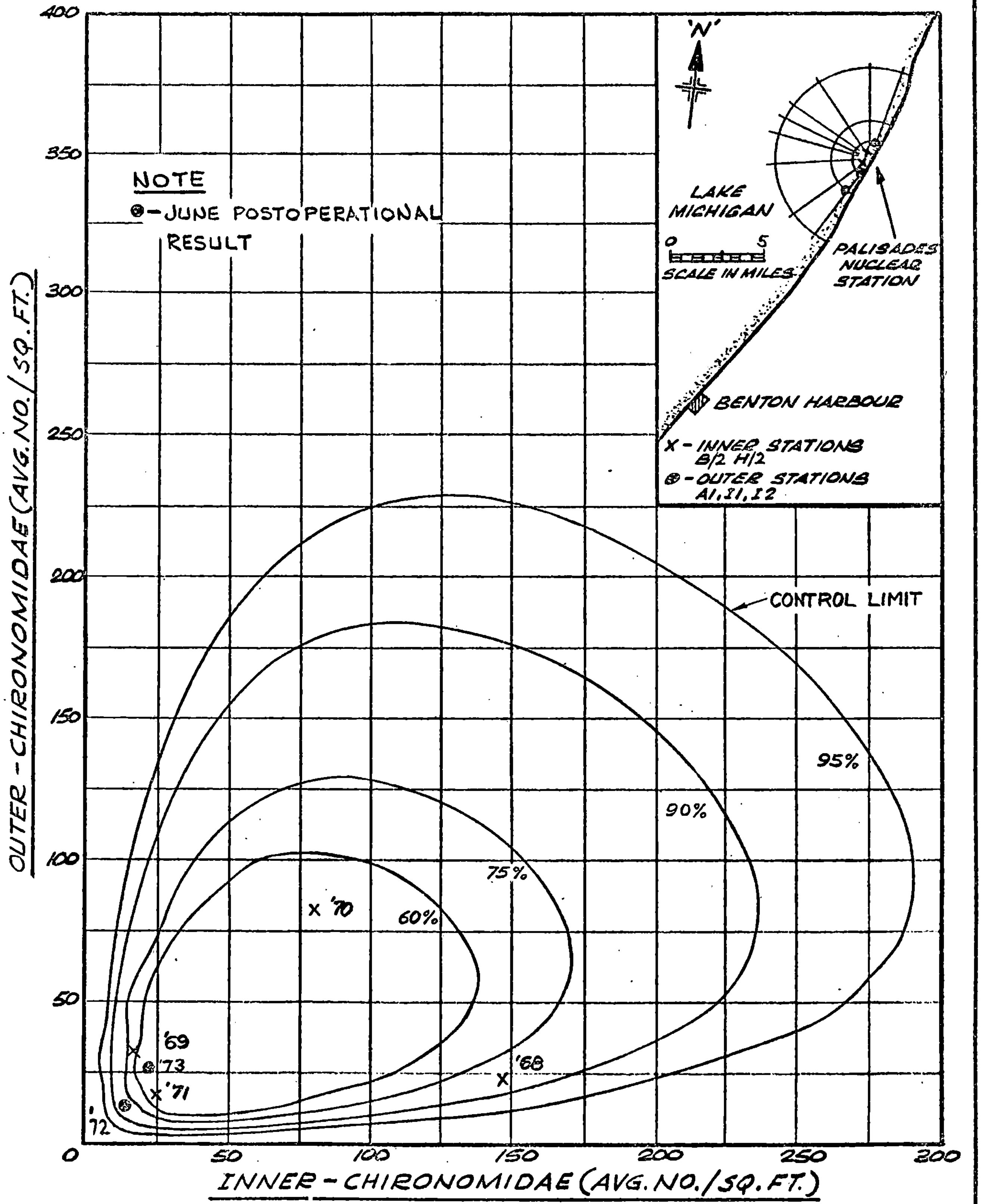
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

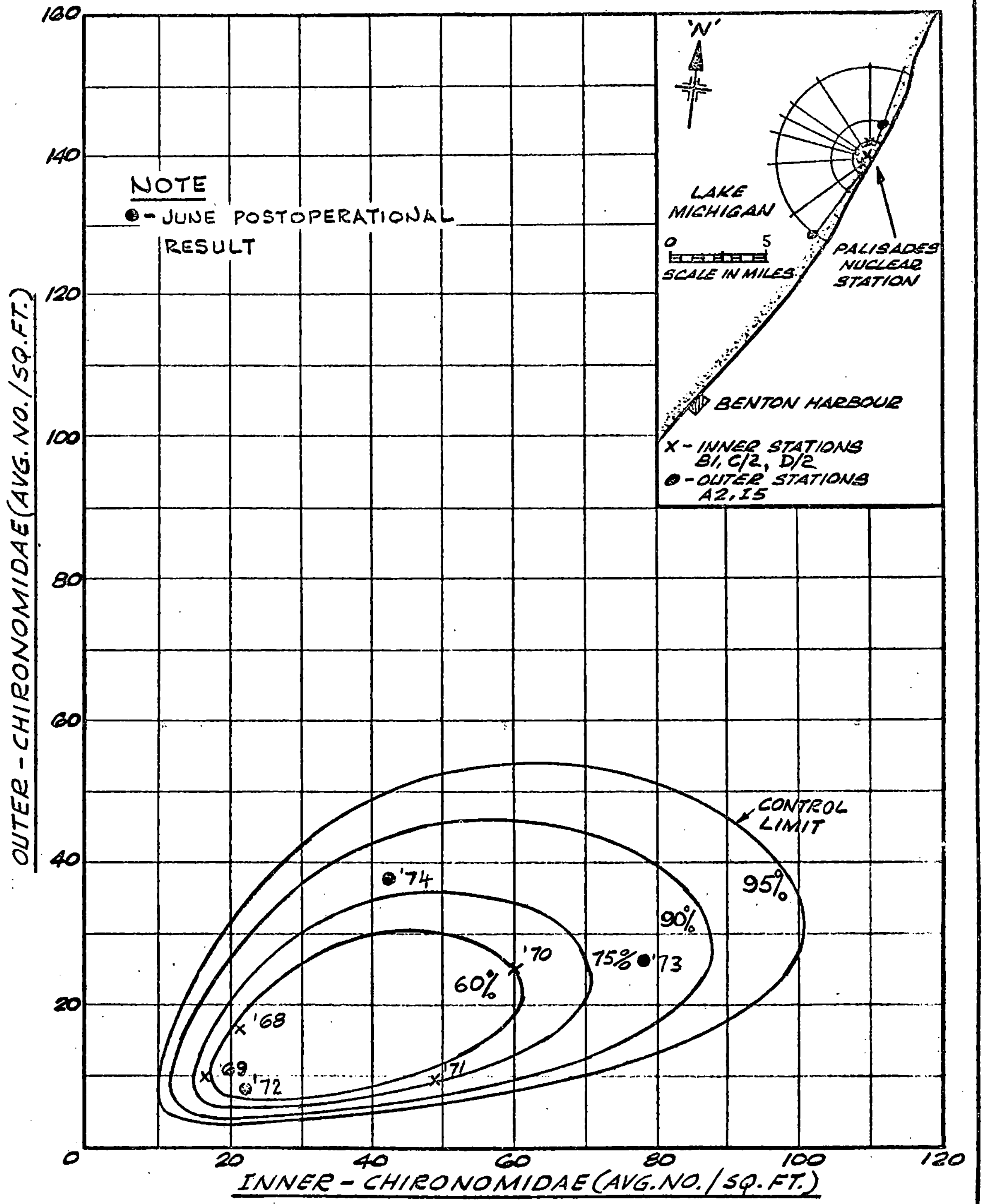
CONSUMERS POWER COMPANY JACKSON – MICHIGAN	BEAK	BY DATE 17-10-73 DWG NO A2048-72	FIG. C-23A

TRANSLAR 003



MIDGE DENSITY - DEPTH LESS THAN 20 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

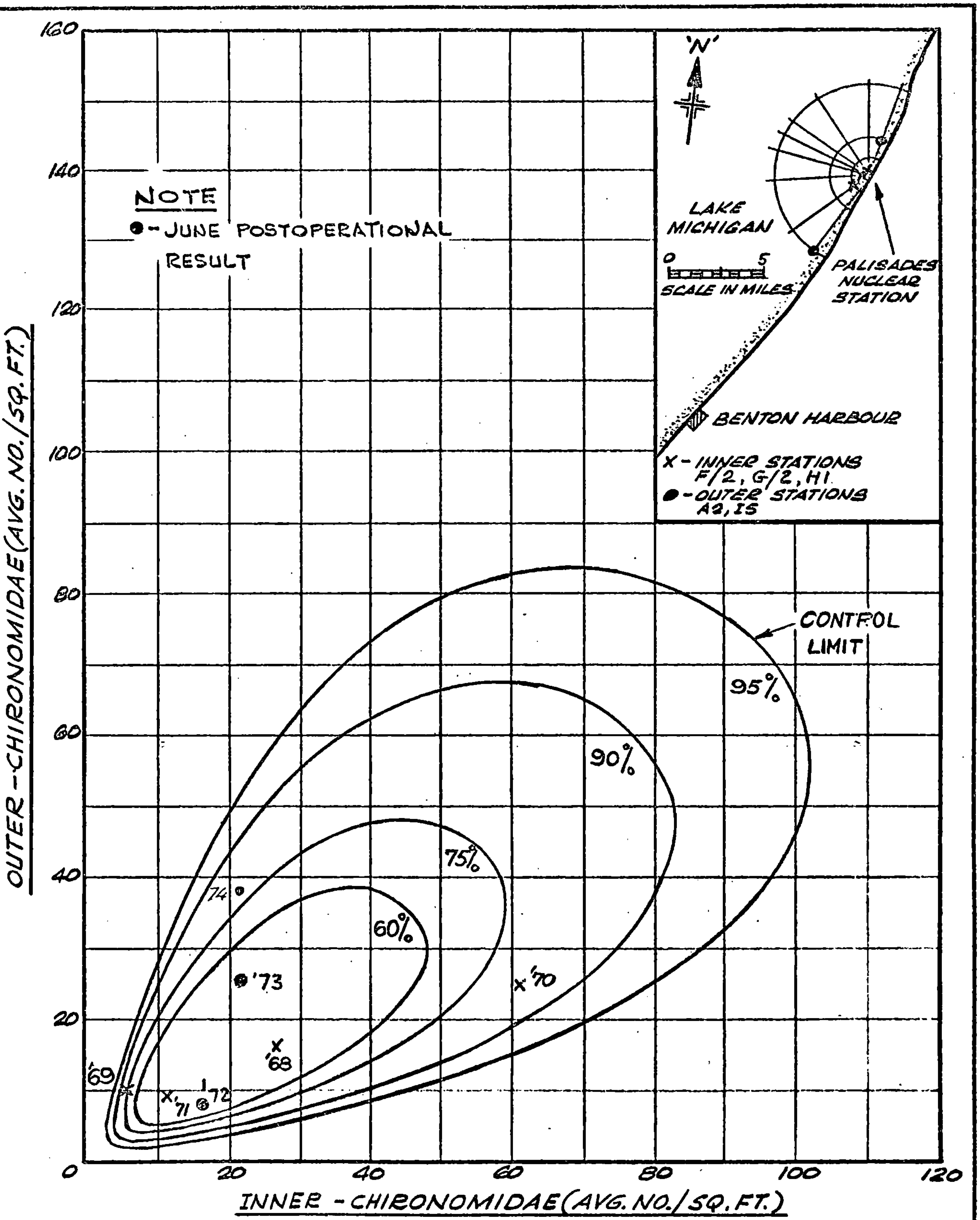
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 16/73 DWG NO A 2048-15	FIG. C-24A



MIDGE DENSITY - NORTH QUADRANT - DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 4.11	BY RCO DATE 13.1.75 DWG NO A 2048-16	FIG. C-25A

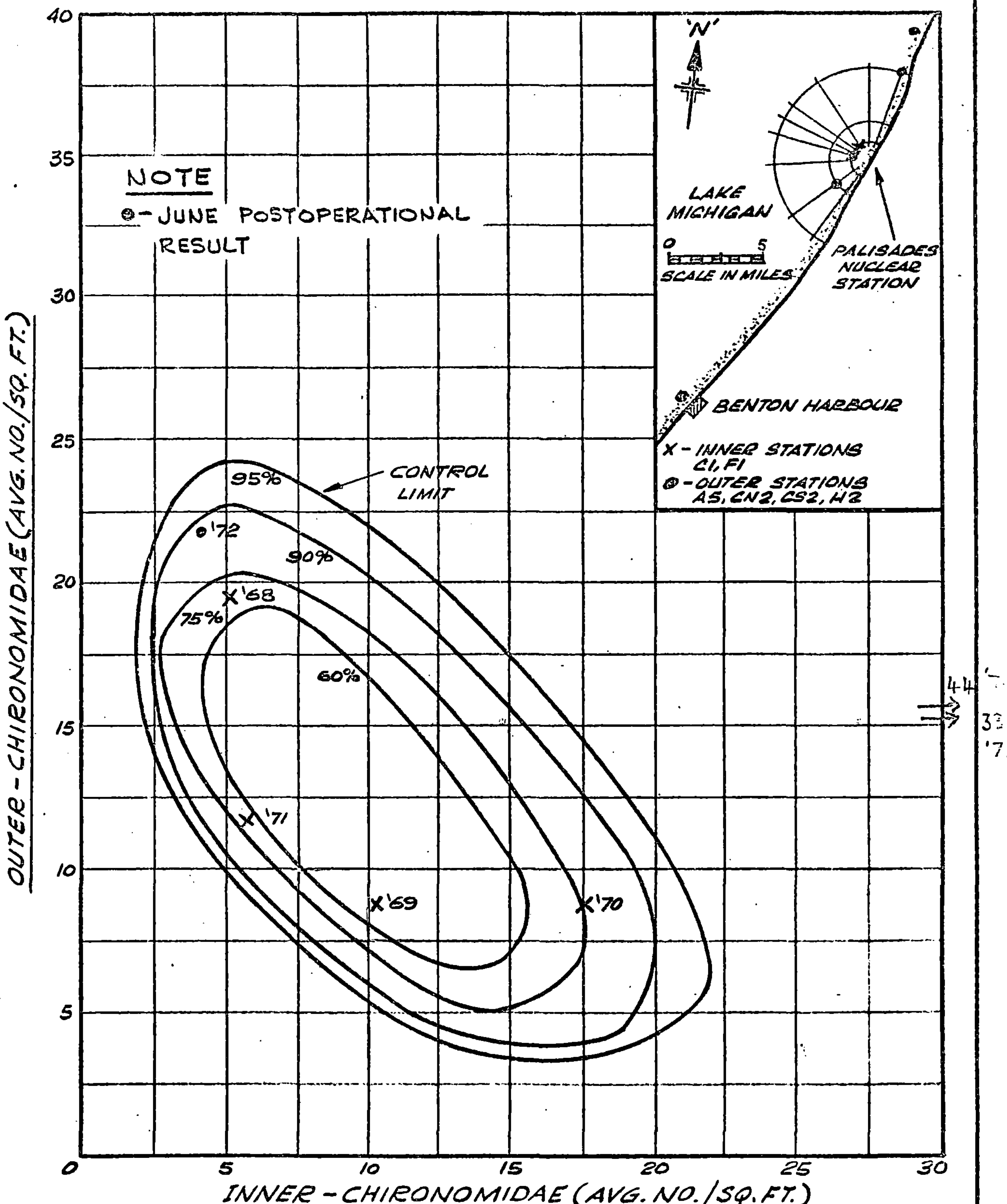
TRANSLAR 003



MIDGE DENSITY - SOUTH QUADRANT - DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 4.12	BY RCD DATE 13·1·75 DWG NO A 2048-17	FIG. C-26A

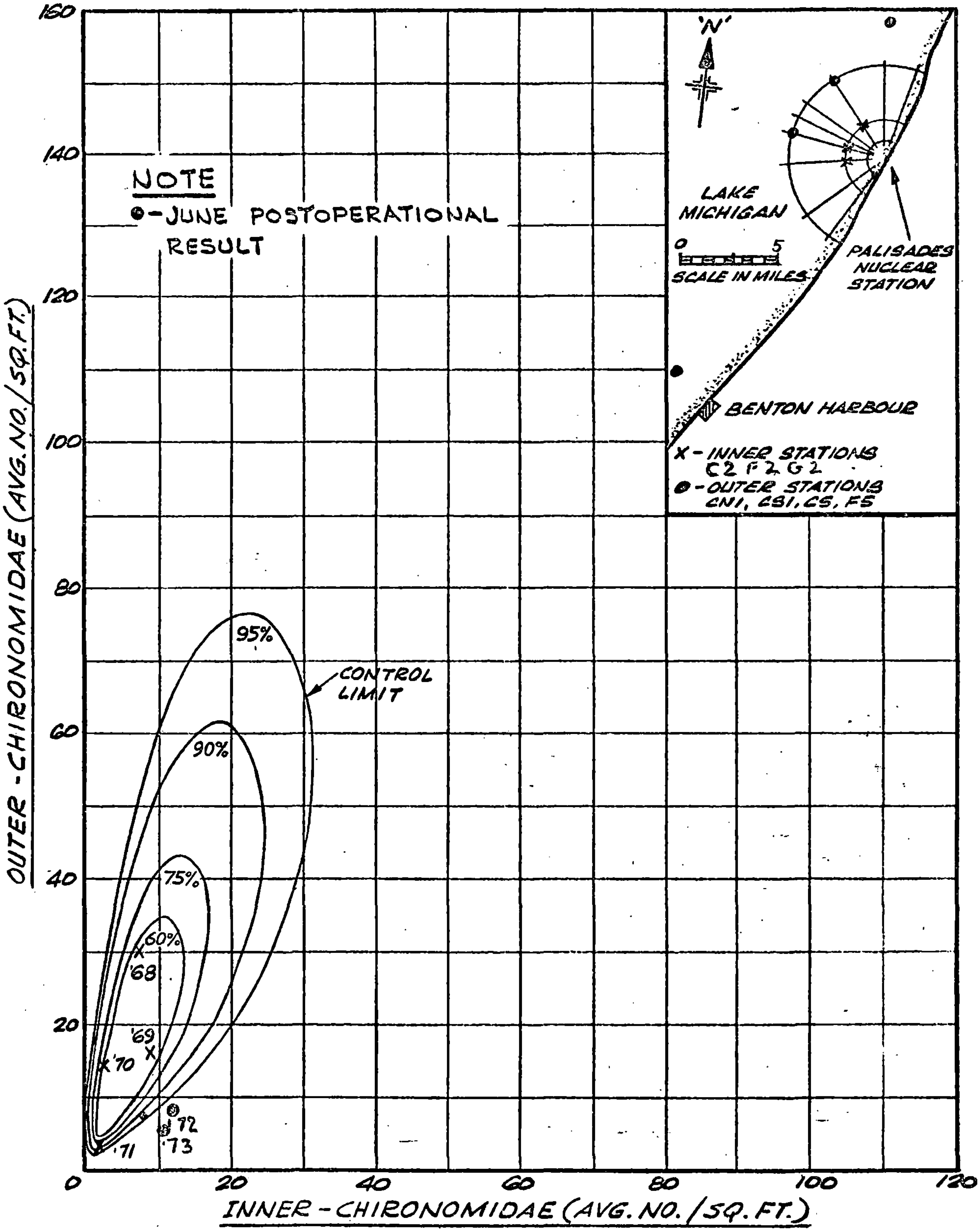
TRANSLAR 003



MIDGE DENSITY - DEPTH 30-50 FT.
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 4.13	BY RCD DATE 13·1·75 DWG NO A 2048-18	FIG. C-27A

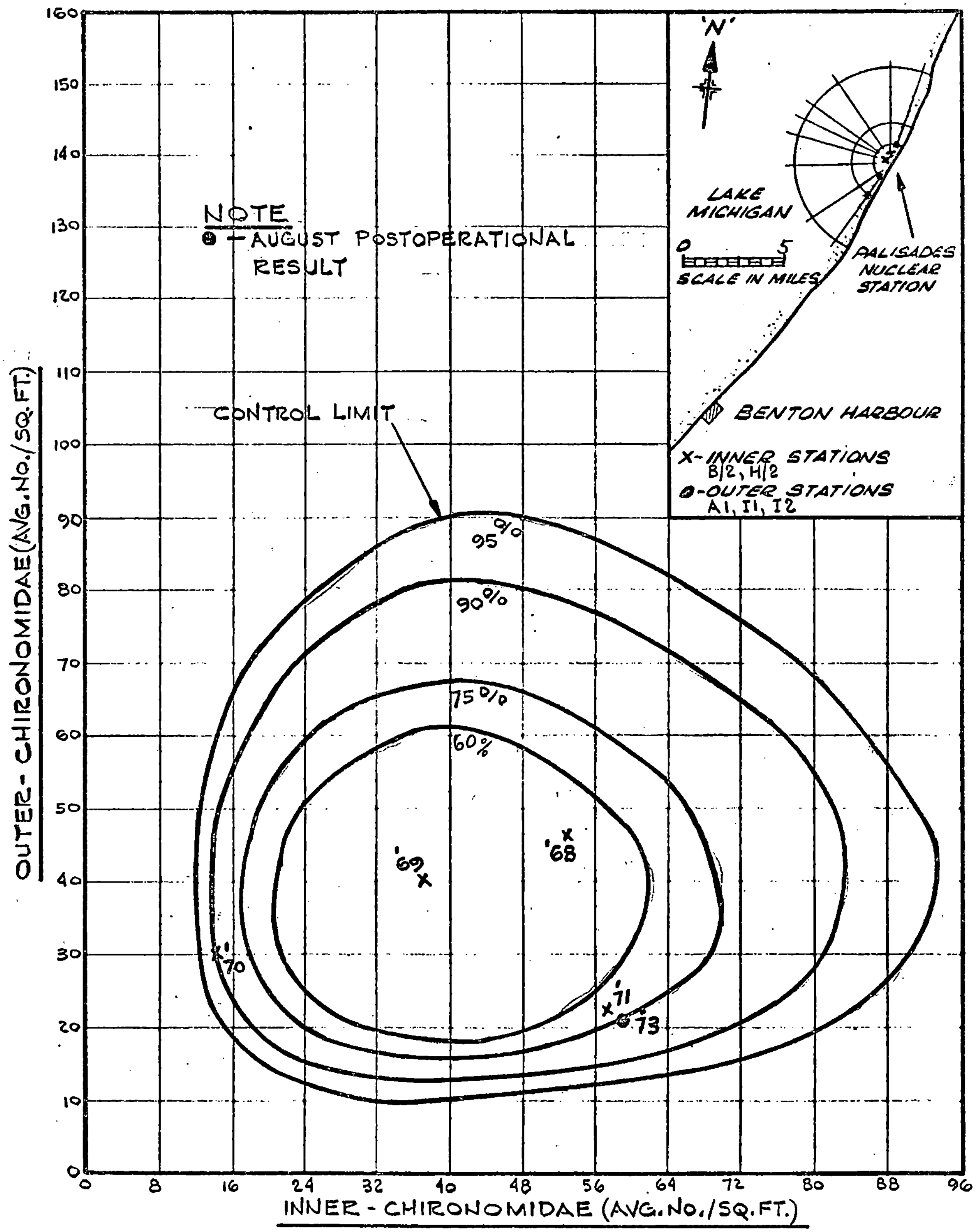
TRANSLAR 003



MIDGE DENSITY - DEPTH GREATER THAN 50FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 16/73 DWG NO A 2048-19	FIG. C-28A

TRANSLAR 003



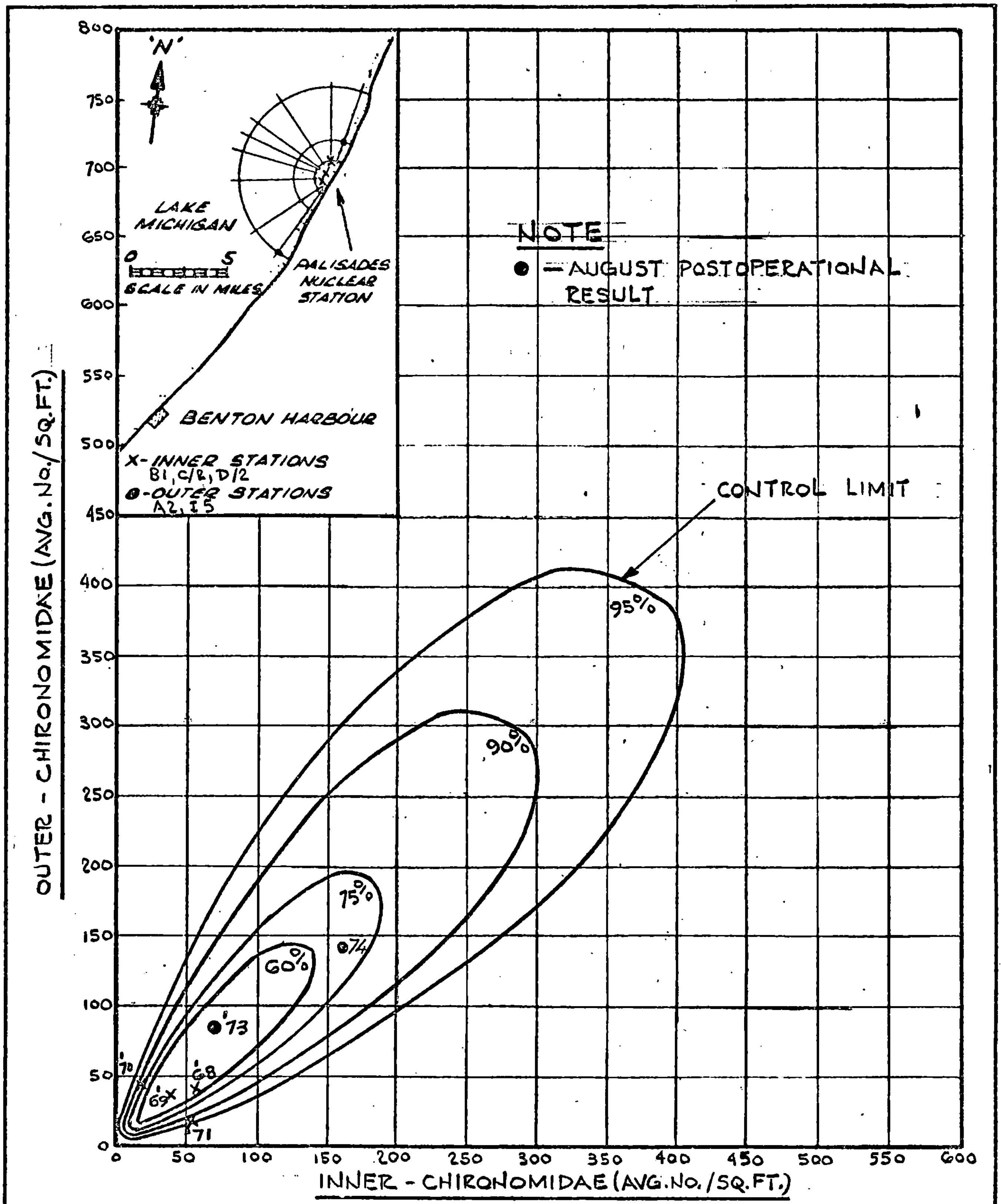
DENSITY OF MIDGES - DEPTH LESS THAN 20 FT.

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY / DATE 17-10-73 DWG NO A 2048-87	FIG. C-29A



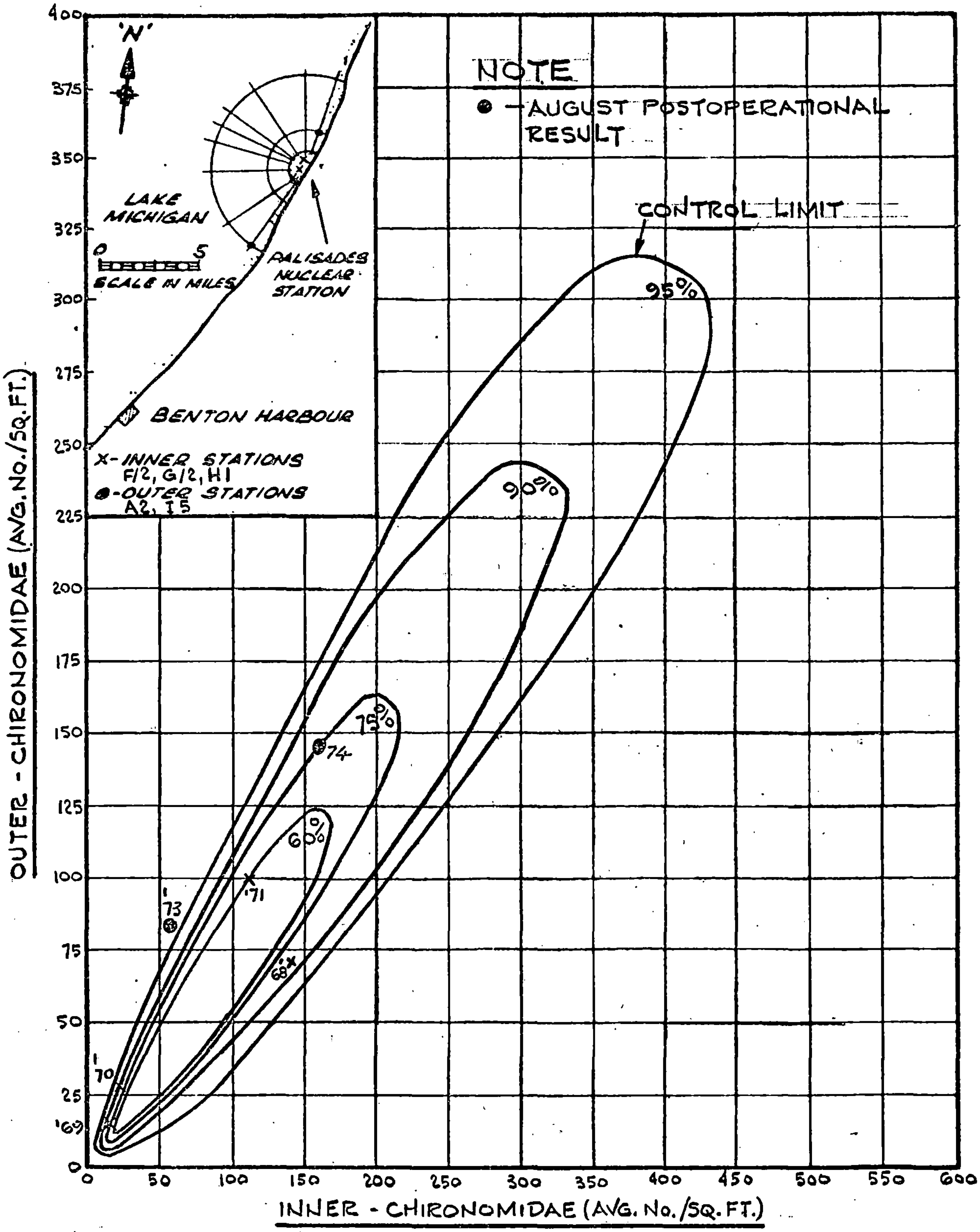
DENSITY OF MIDGES - NORTH QUADRANT - DEPTH 20-30 FT.

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	9.7 BEAK	BY DATE 13-1-75 DWG NO A 2048-88	FIG. C-30A



DENSITY OF MIDGES - SOUTH QUADRANT - DEPTH 20-30FT.

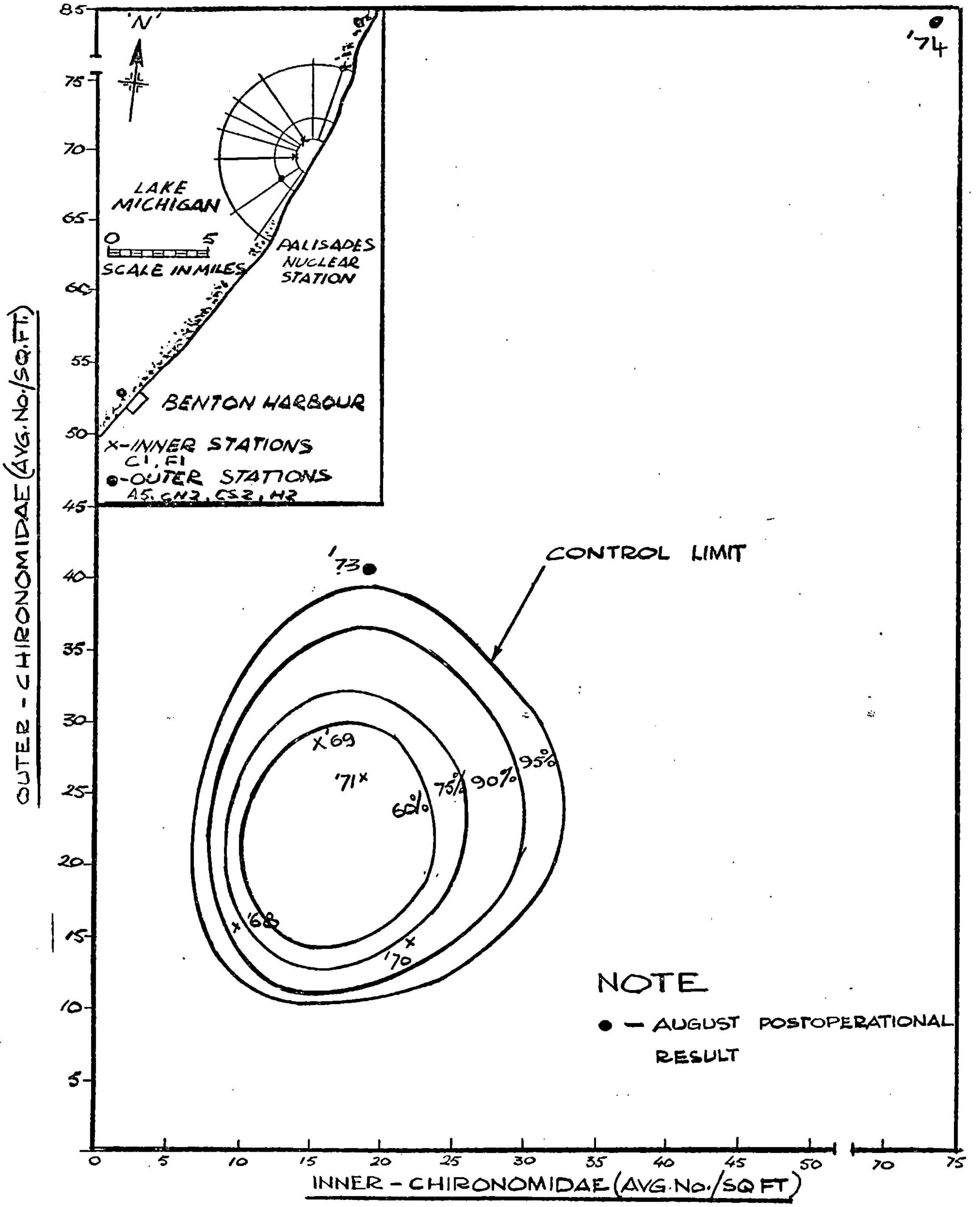
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK 9.8	BY DATE 13·1·75 DWG NO A 2048 - 89	*FIG.* C-31A

TRANSLAR 003



DENSITY OF MIDGES — DEPTH 30-50FT

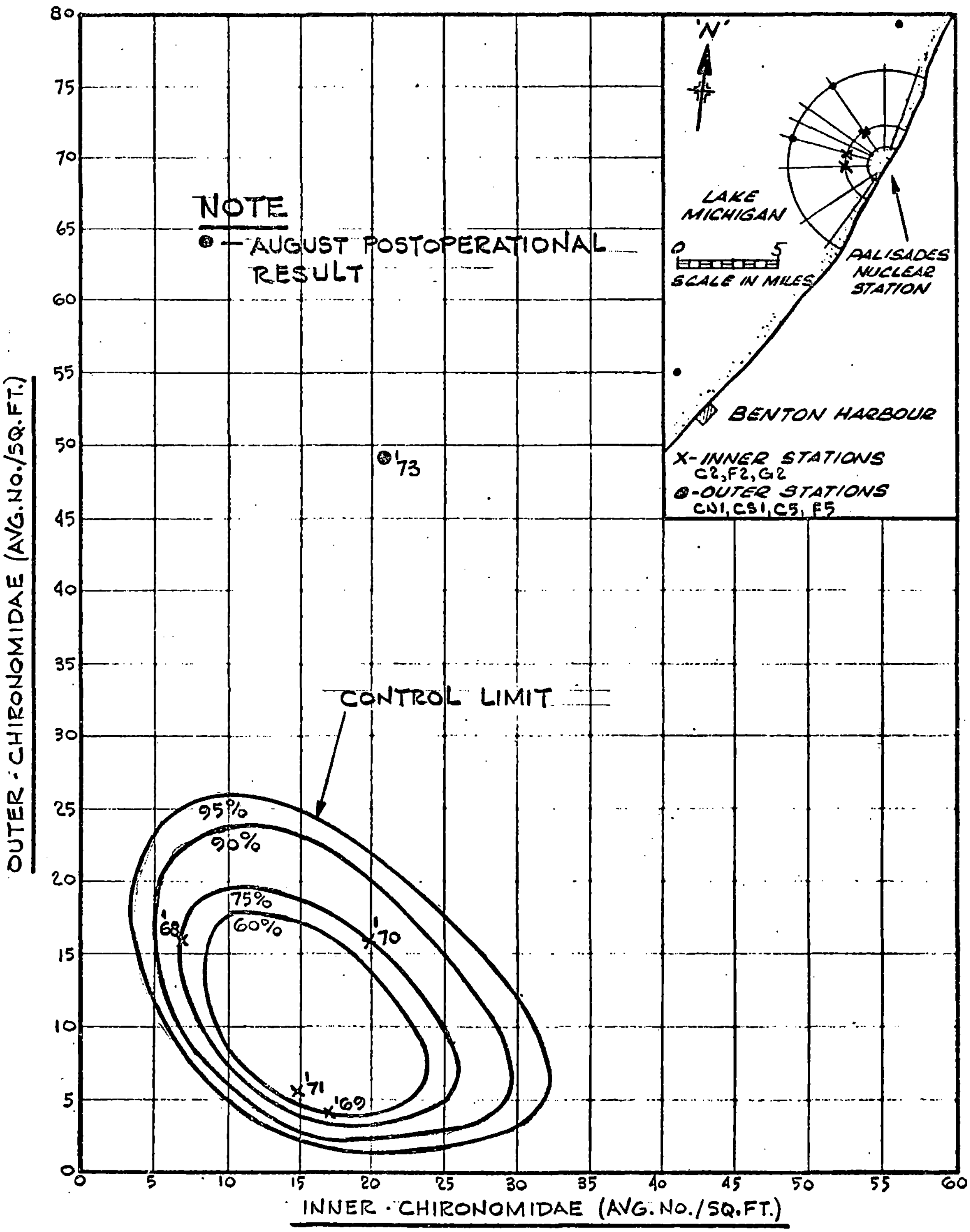
AUGUST BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY / DATE 16.1.75 DWG. NO. A 2048-90	FIG. C-32A

TRANSLAR 250-12-73 134



DENSITY OF MIDGES - DEPTH GREATER THAN 50FT.

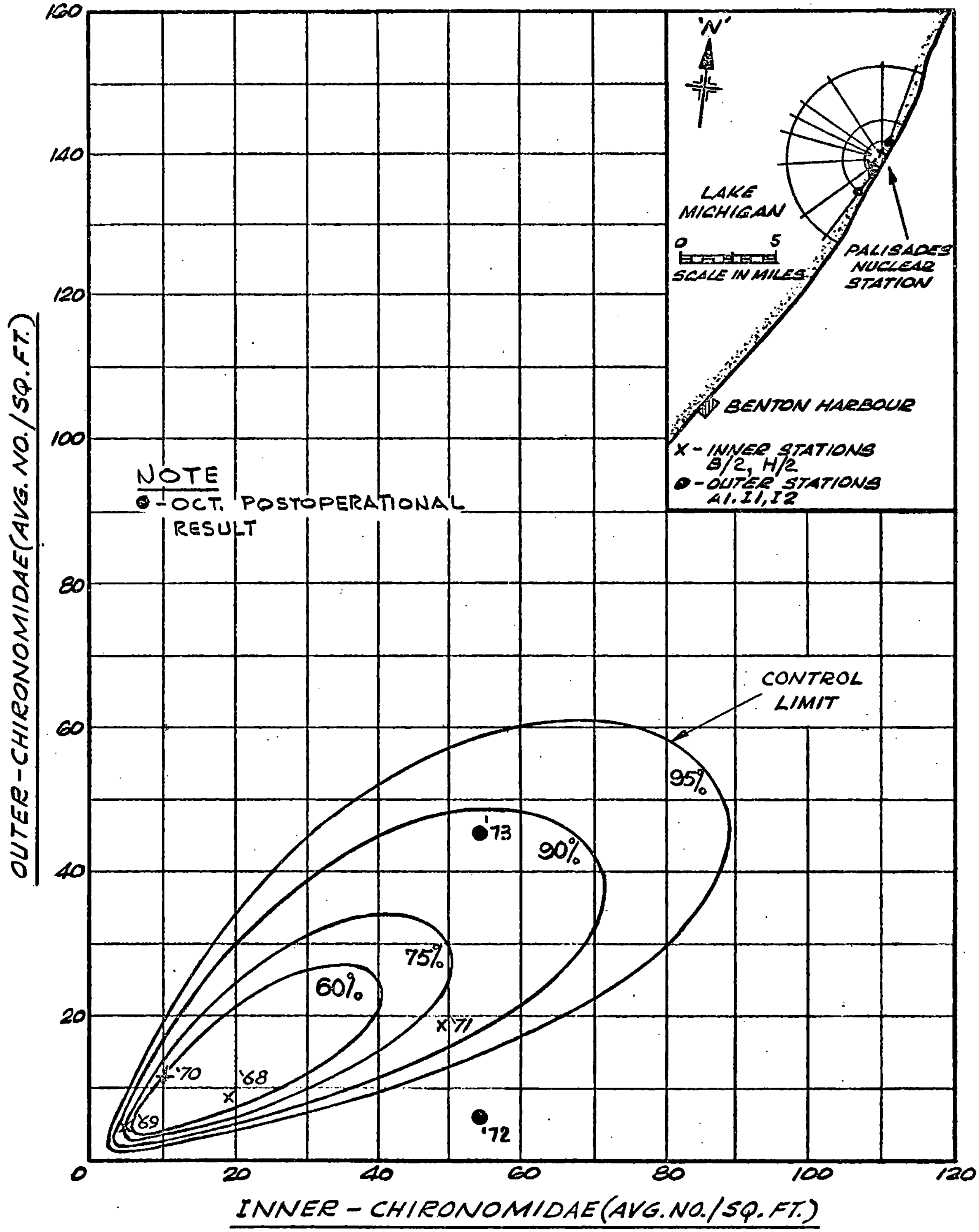
AUGUST BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

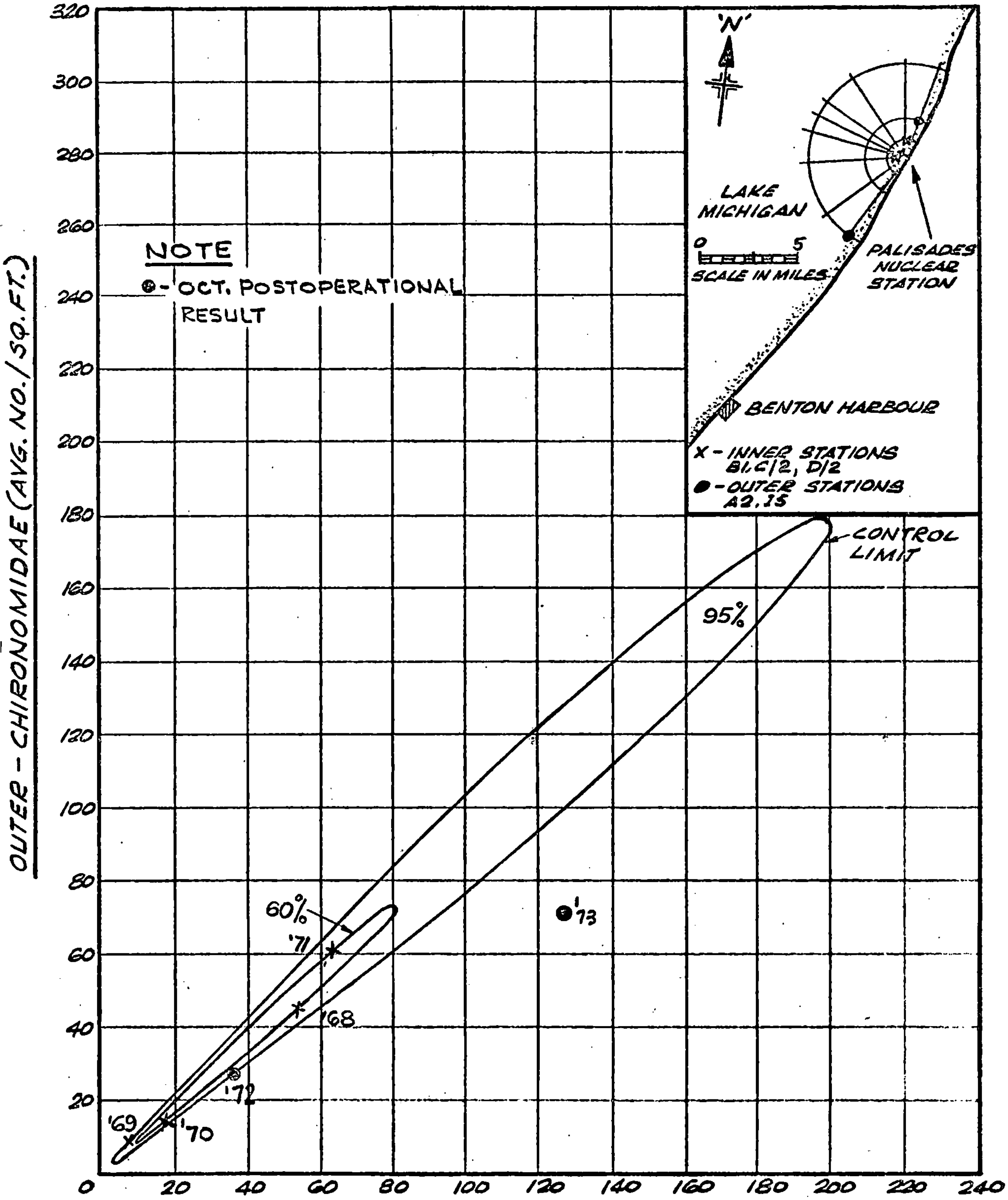
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY DWG NO A 2048 - 91	DATE 17-10-73	FIG. C-33A

TRANSLAR 003



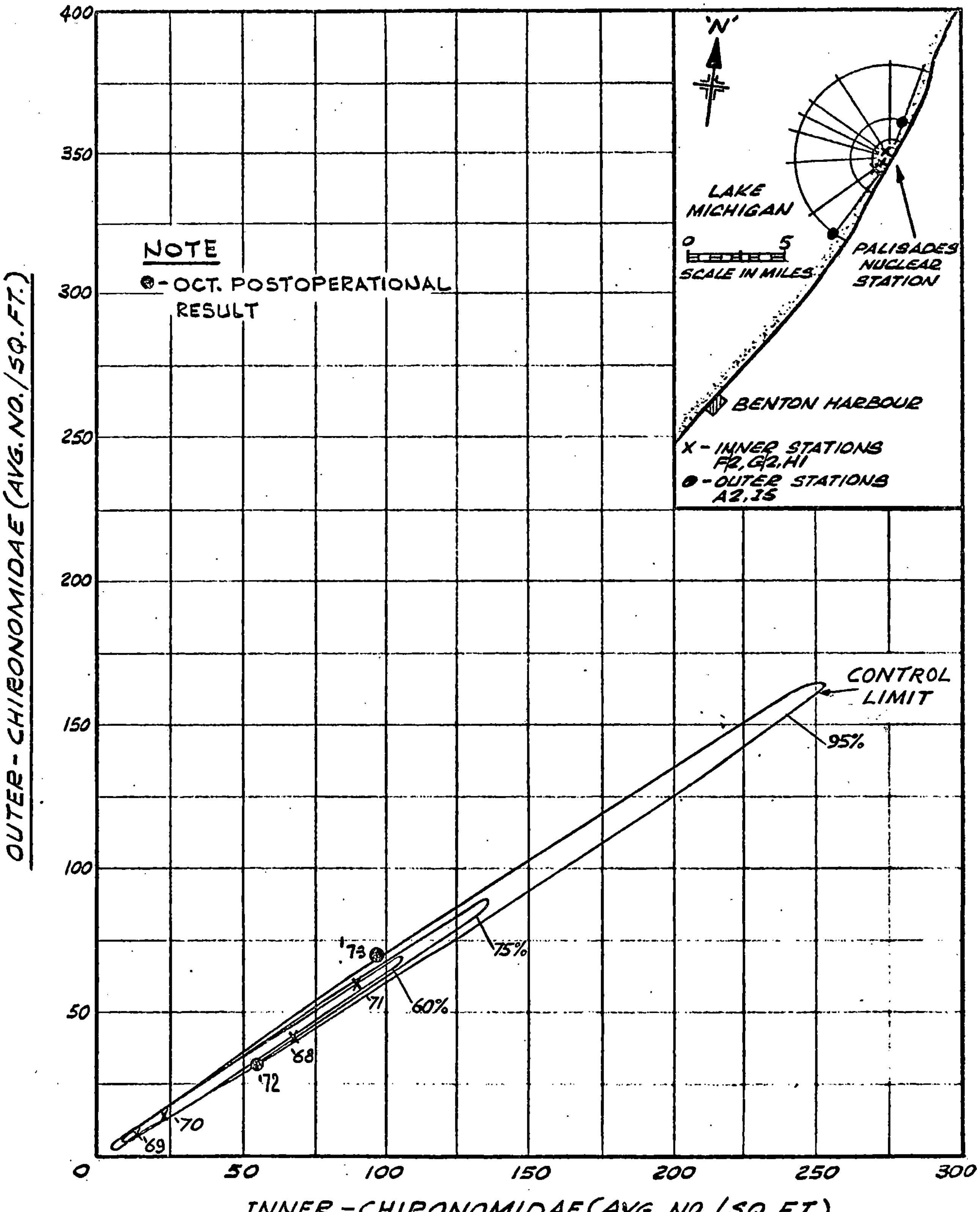
DENSITY OF MIDGES - DEPTH LESS THAN 20 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 16/73 DWG NO A 2048-35	FIG. C-34A



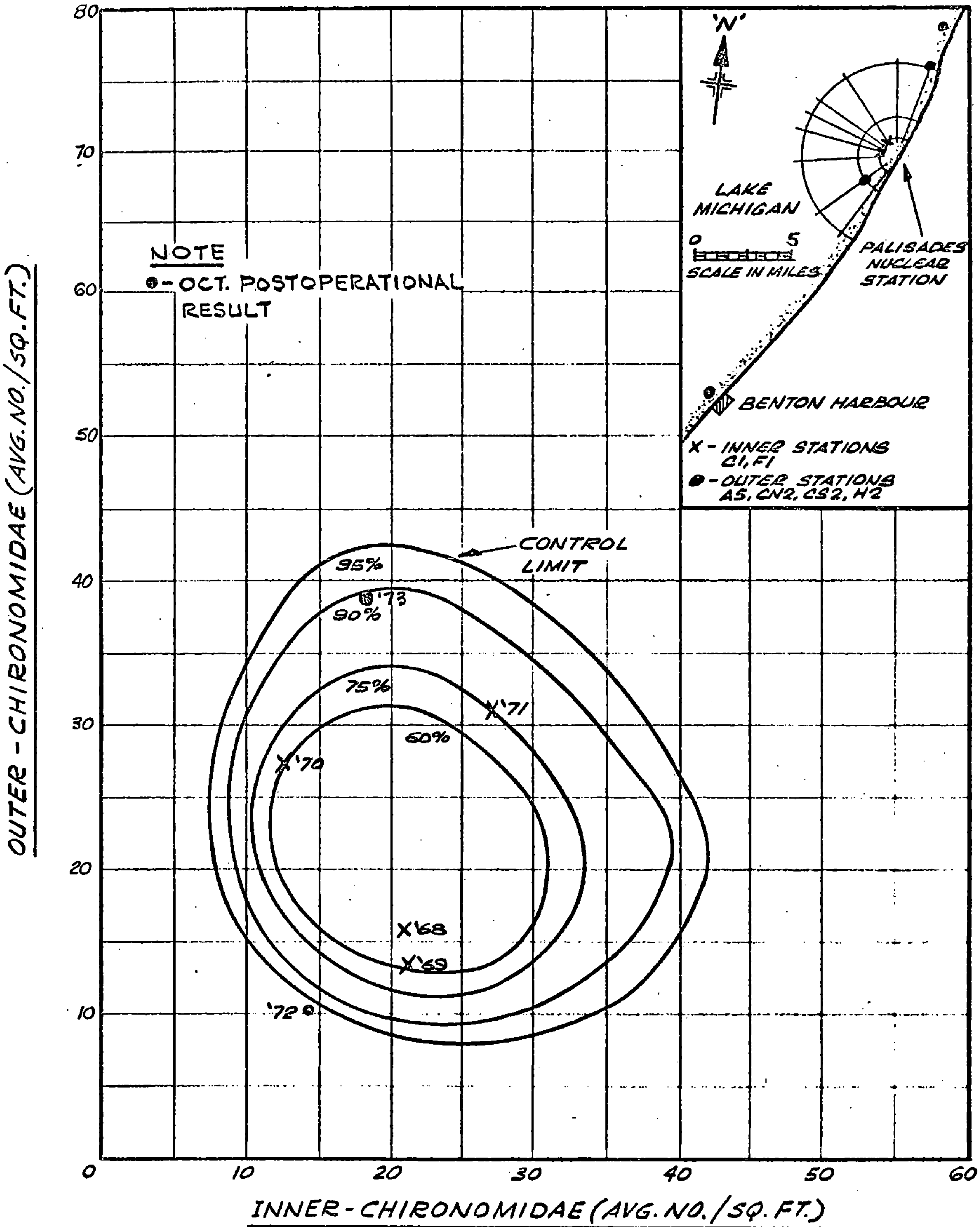
DENSITY OF MIDGES - NORTH QUADRANT - DEPTH 20-30 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 5.11	BY RCD	DATE JAN 16/73	FIG.
		DWG NO A 2048-36		C-35A



DENSITY OF MIDGES - SOUTH QUADRANT - DEPTH 20-30 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

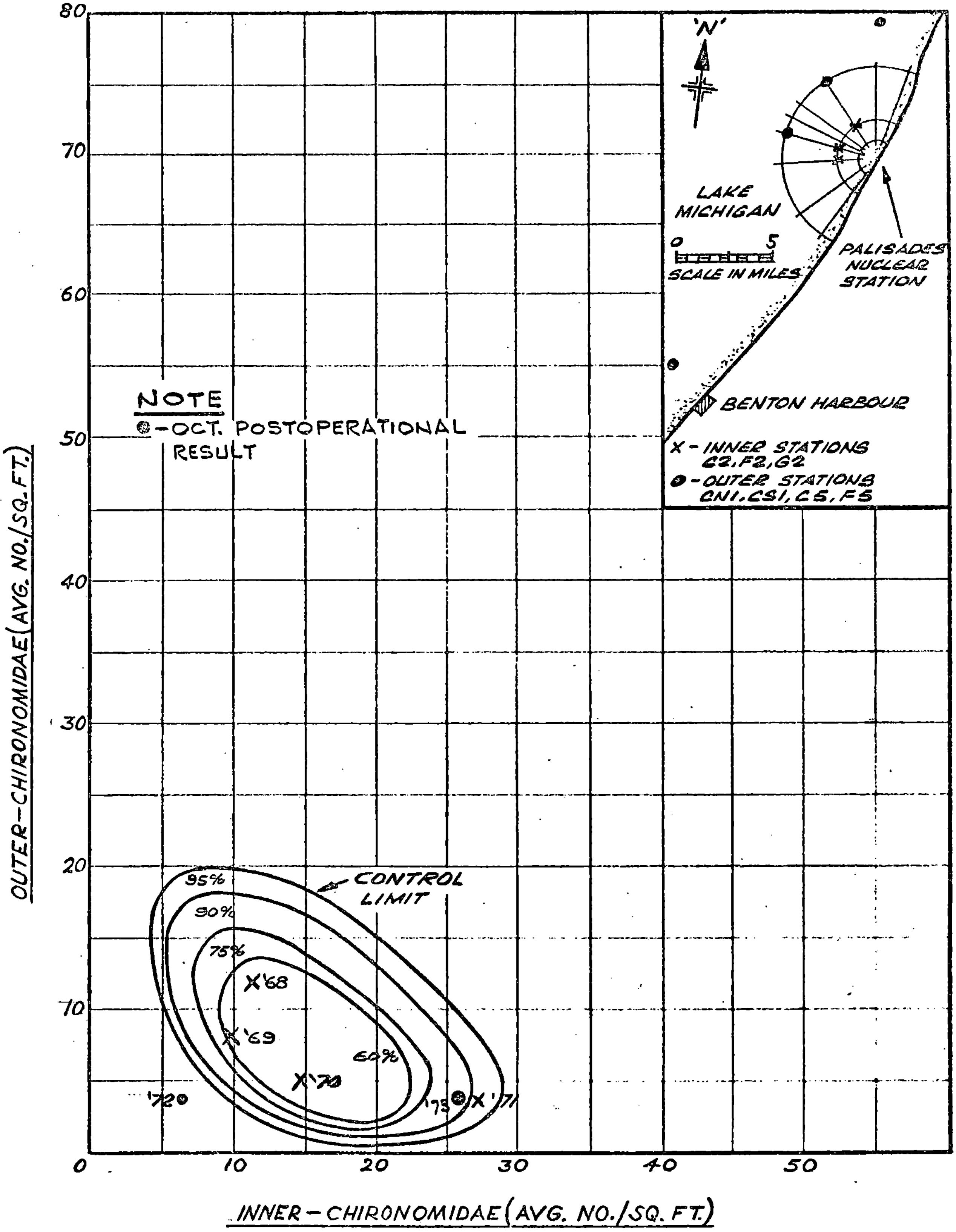
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY S.R. DATE JAN 16/73 DWG NO A 2048-37	FIG. C-36A



DENSITY OF MIDGES - DEPTH 30-50 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY S.R. DATE JAN 16/73 DWG NO A 2048-38	FIG. C-37A

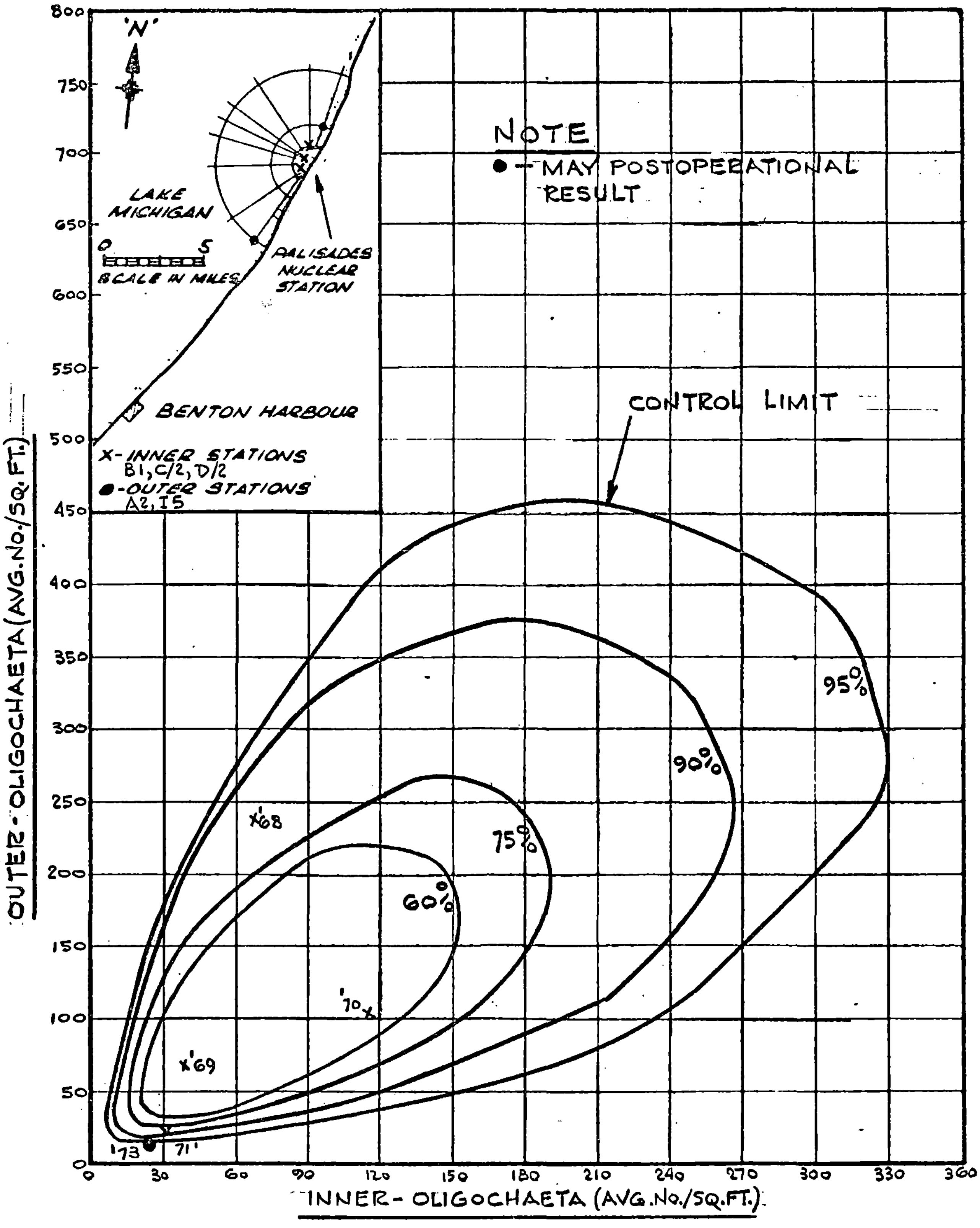
TRANSLAR 003



DENSITY OF MIDGES - DEPTH GREATER THAN 50FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY D.C.S. DATE JAN 16/73 DWG NO A 2048-39	FIG. C-38A

TRANSLAR 003



DENSITY OF SEGMENTED WORMS-NORTH QUADRANT-DEPTH 20-30 FT.

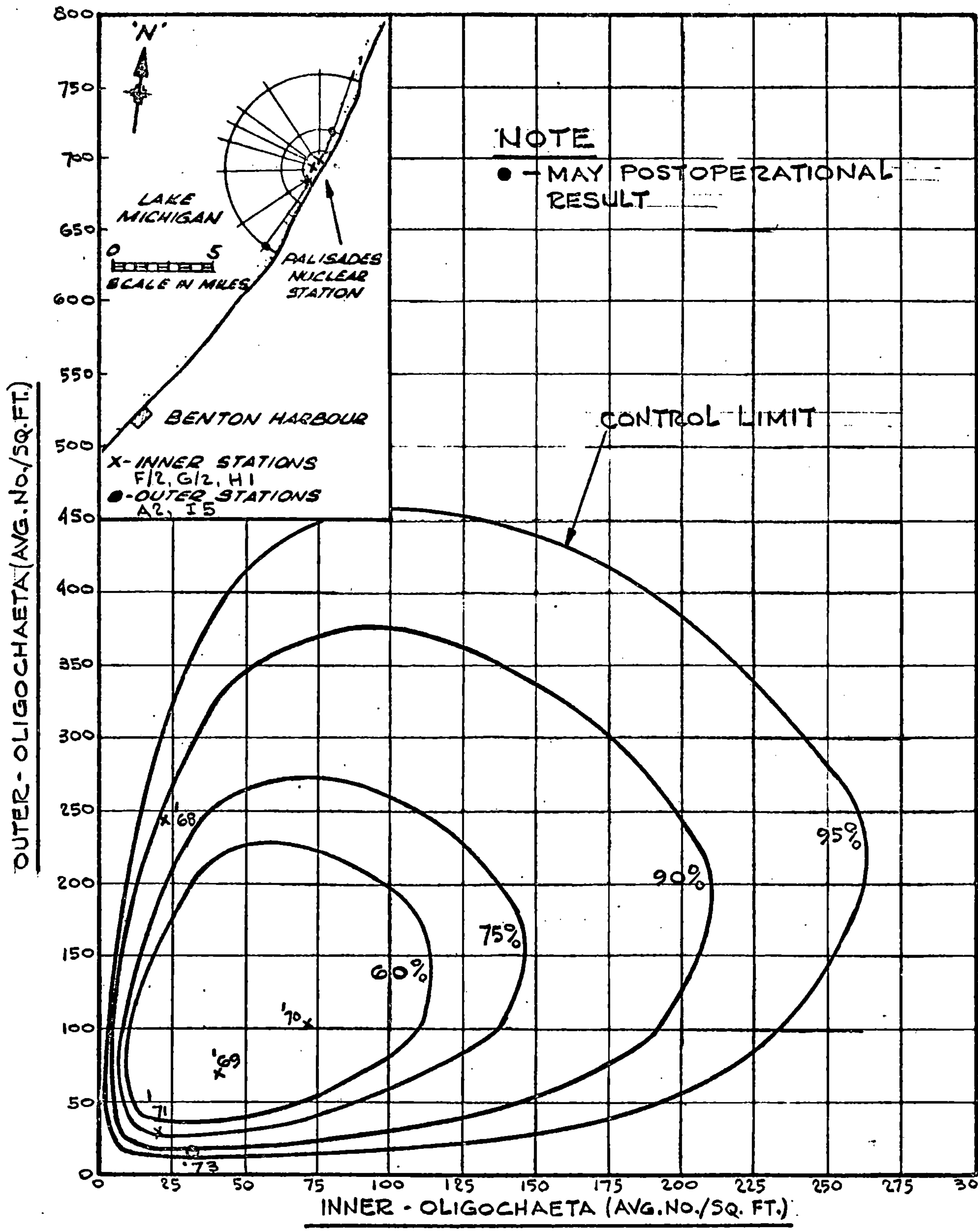
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY DATE 17-10-73 DWG NO A 2048-74	FIG. C-39A

TRANSLAR 003



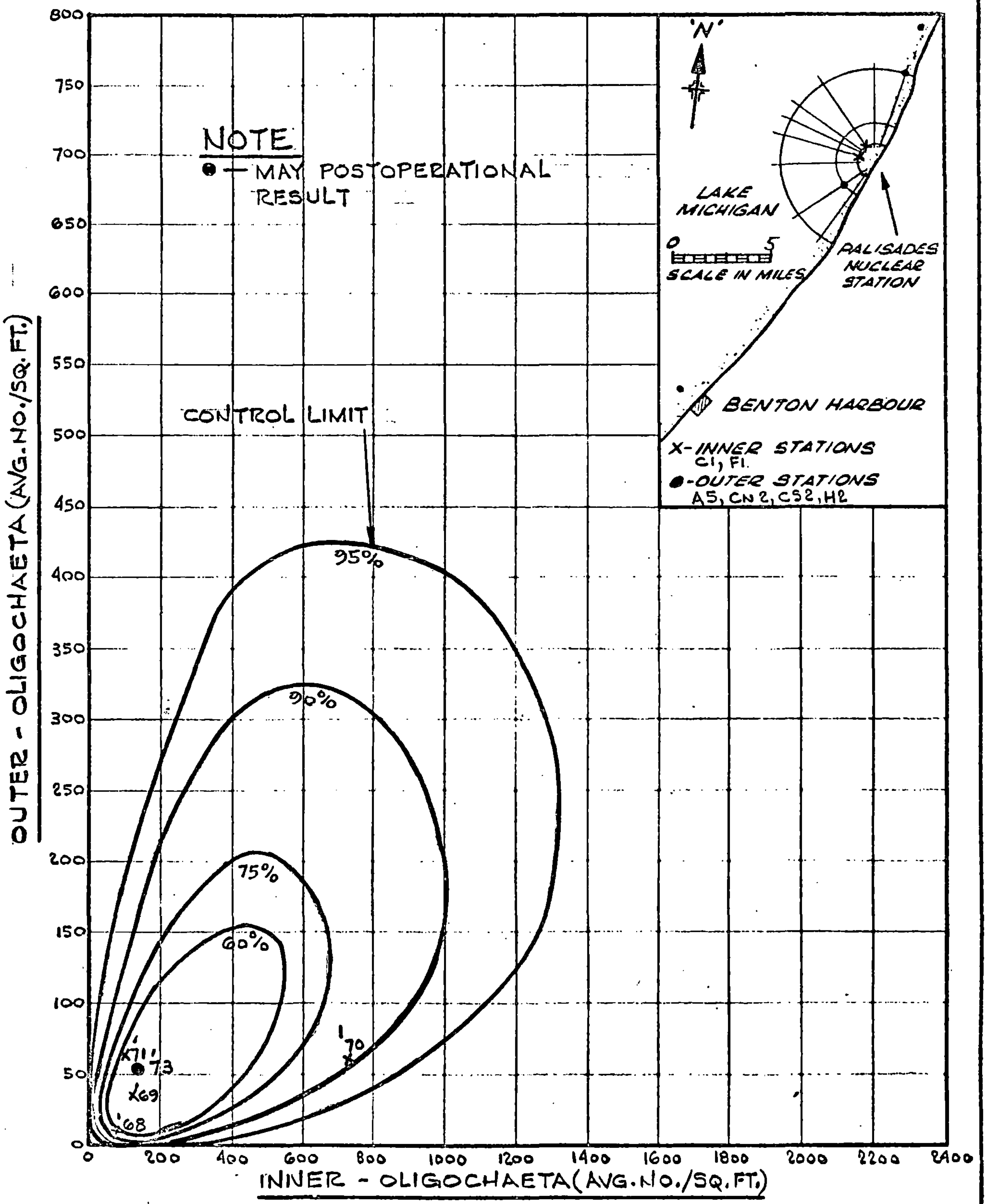
DENSITY OF SEGMENTED WORMS - SOUTH QUADRANT - DEPTH 20-30 FT.

MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO A 2048 -75	FIG. C-40A



DENSITY OF SEGMENTED WORMS - DEPTH 30-50FT.

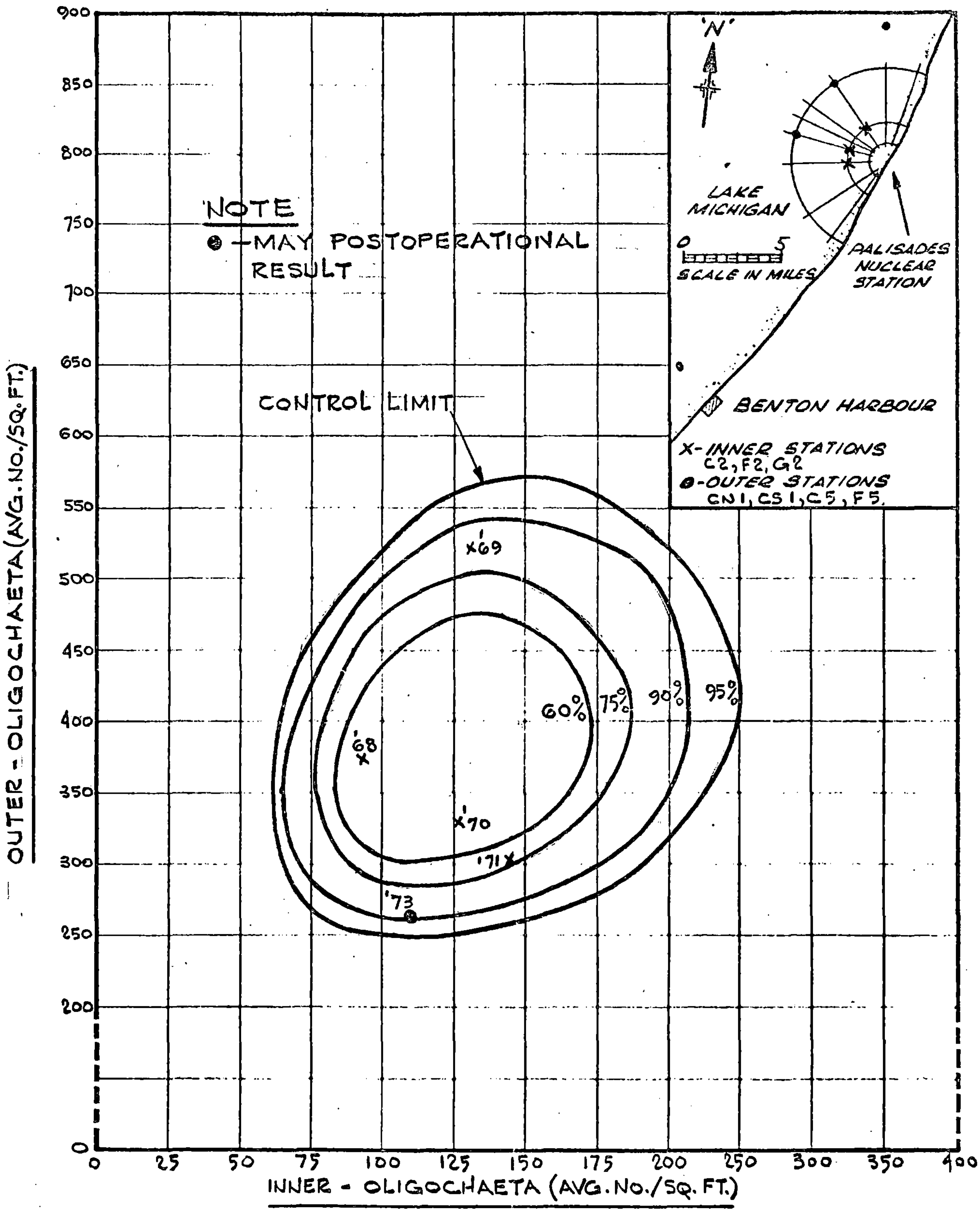
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY / DATE 17-10-73 / DWG NO A 2048-76	FIG. C-41A

TRANSLAR 003



DENSITY OF SEGMENTED WORMS - DEPTH - GREATER THAN 50 FT.

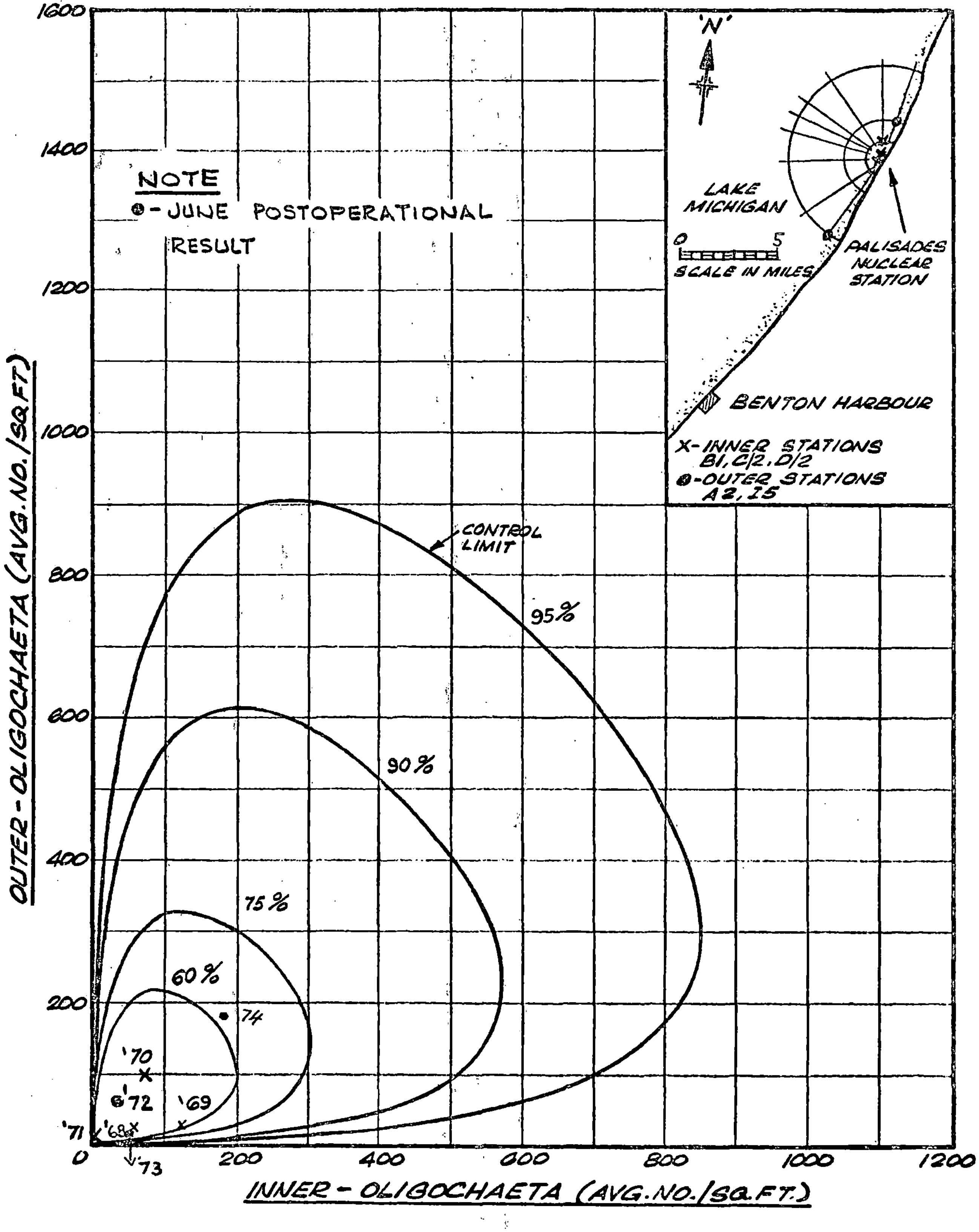
MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON – MICHIGAN	BEAK	BY DATE 17-10-73 DWG NO A2048-77	FIG. C-42A

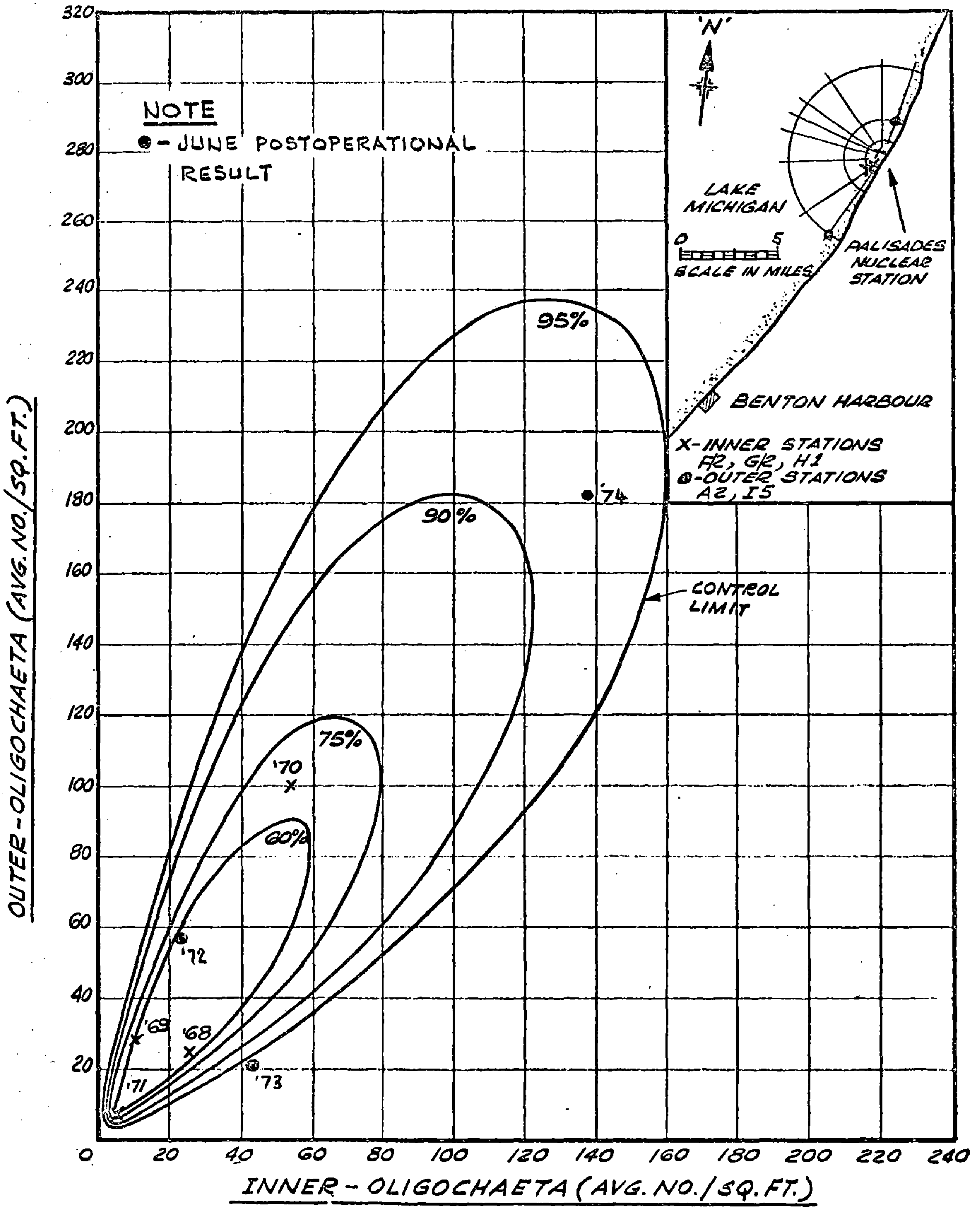
TRANSLAR 003



DENSITY OF SEGMENTED WORMS - NORTH QUADRANT - DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

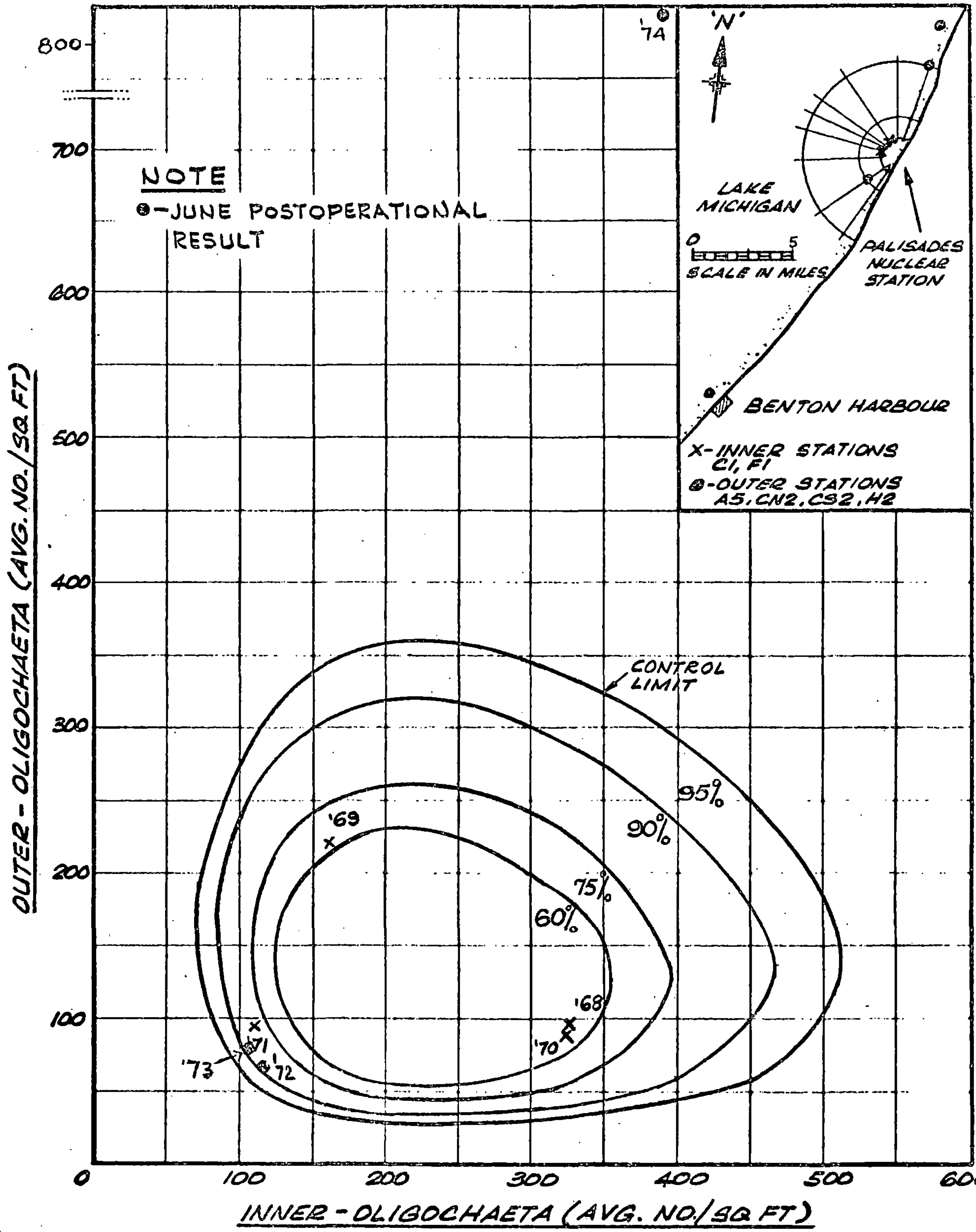
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 4.15	BY RCD DATE 3·1·75 DWG NO A 2048 - 20	FIG. C-43A

TRANSLAR 003



DENSITY OF SEGMENTED WORMS - SOUTH QUADRANT - DEPTH 20-30FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

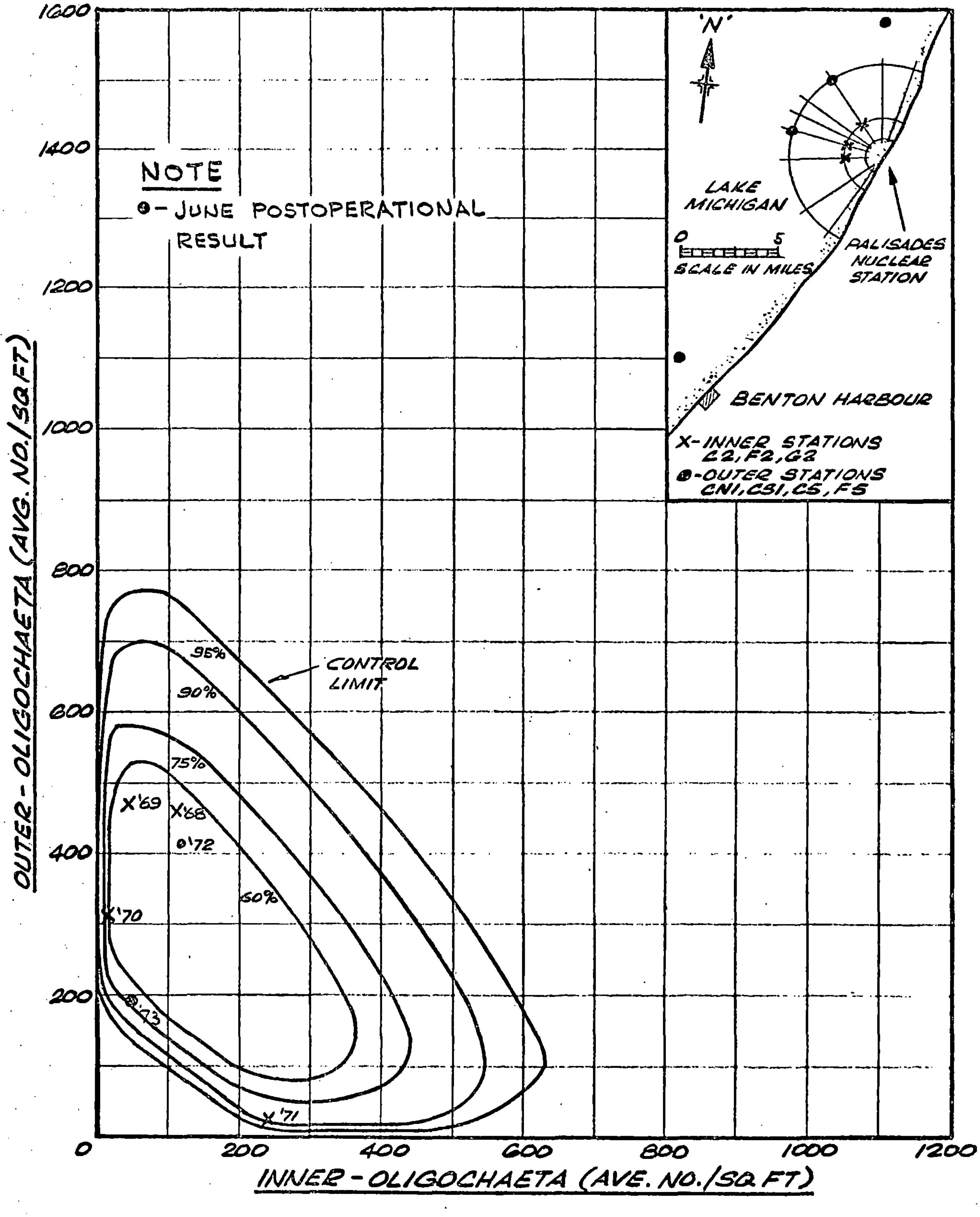
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	4.16 BEAK	BY S. R. DATE 13.1.75 DWG NO A 2048 - 21	FIG. C-44A



DENSITY OF SEGMENTED WORMS - DEPTH 30-50 FT.
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

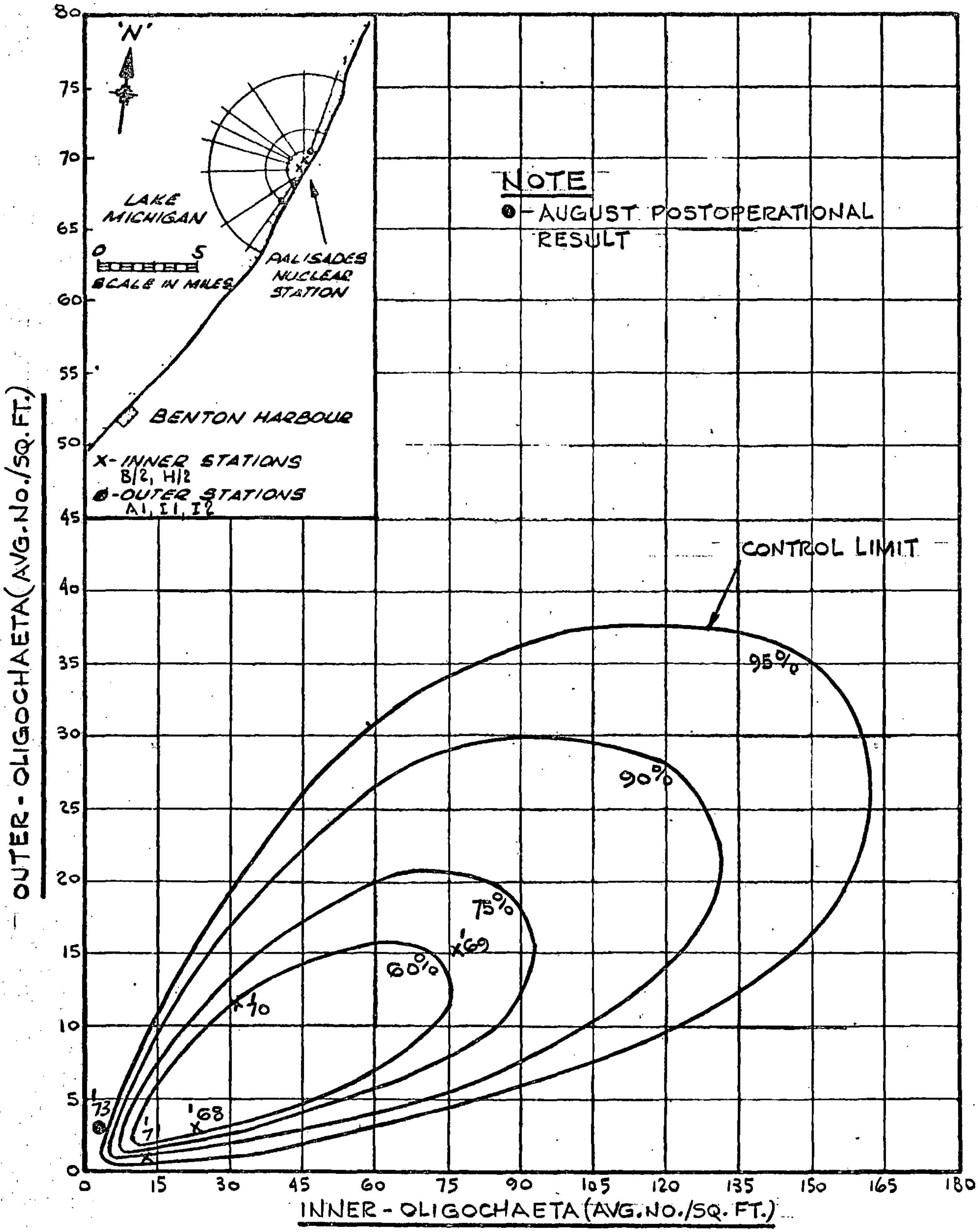
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 4.17	BY RCD DATE 13.1.75 DWG NO A 2048-22	FIG. C-45A

TRANSLAR 003



DENSITY OF SEGMENTED WORMS - DEPTH GREATER THAN 50FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 15/73 DWG NO A 2048 - 23	FIG. C-46A



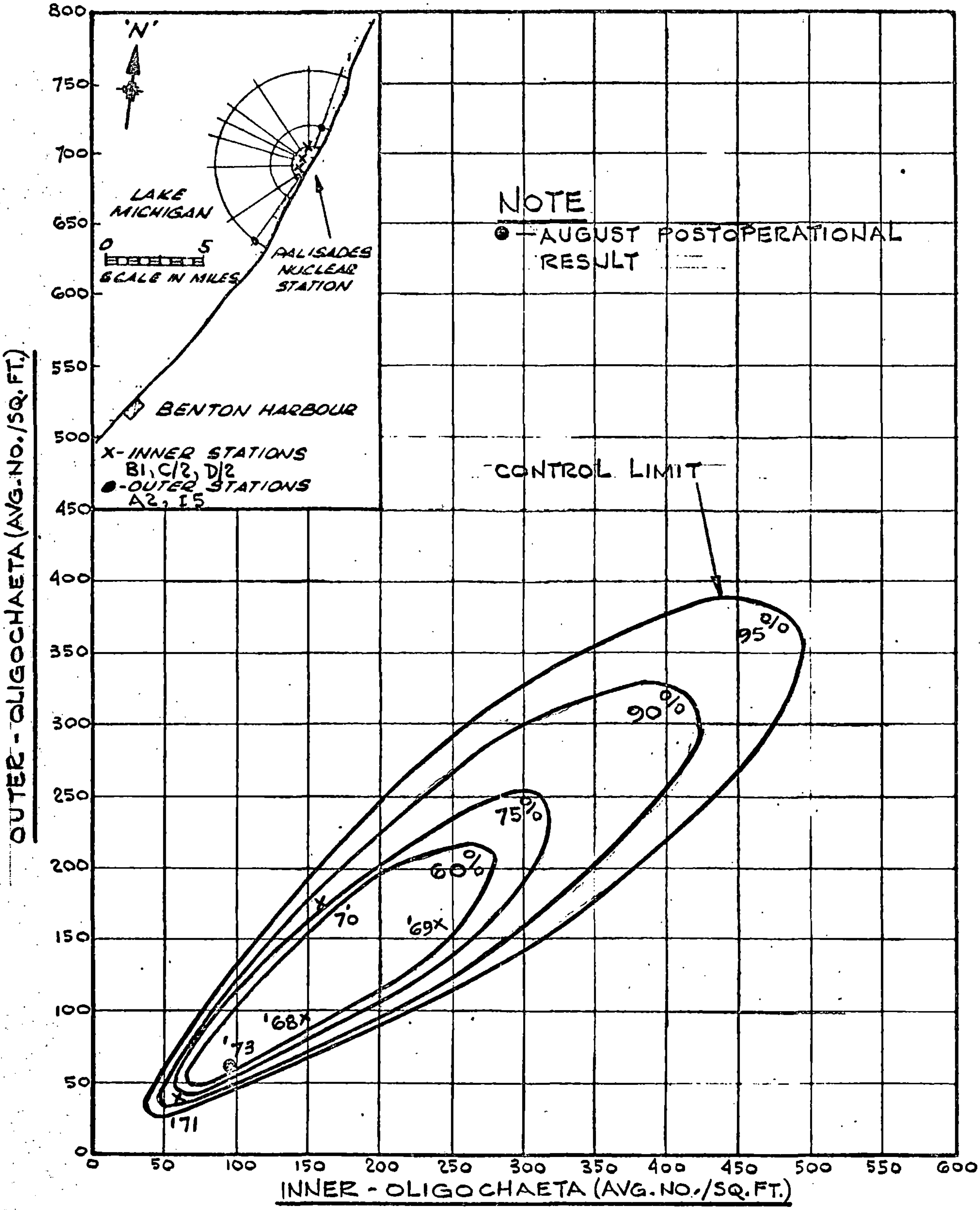
DENSITY OF SEGMENTED WORMS - DEPTH LESS THAN 20 FT.

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO *A 2048 - 92*	*FIG.* C-47A



DENSITY OF SEGMENTED WORMS - NORTH QUADRANT - DEPTH 20-30 FT.

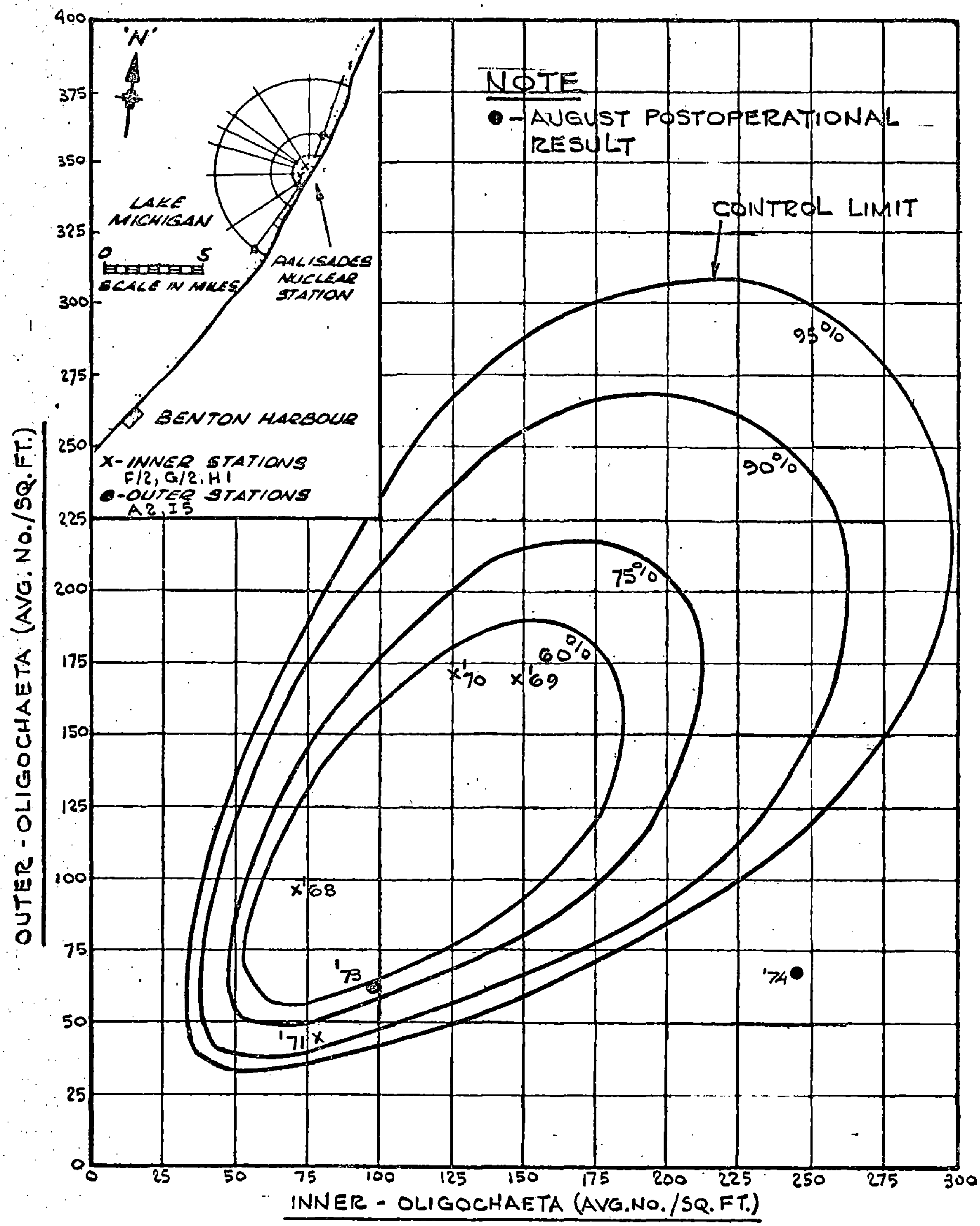
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO A 2048 - 93	*FIG.* C-48A

TRANSLAR 003



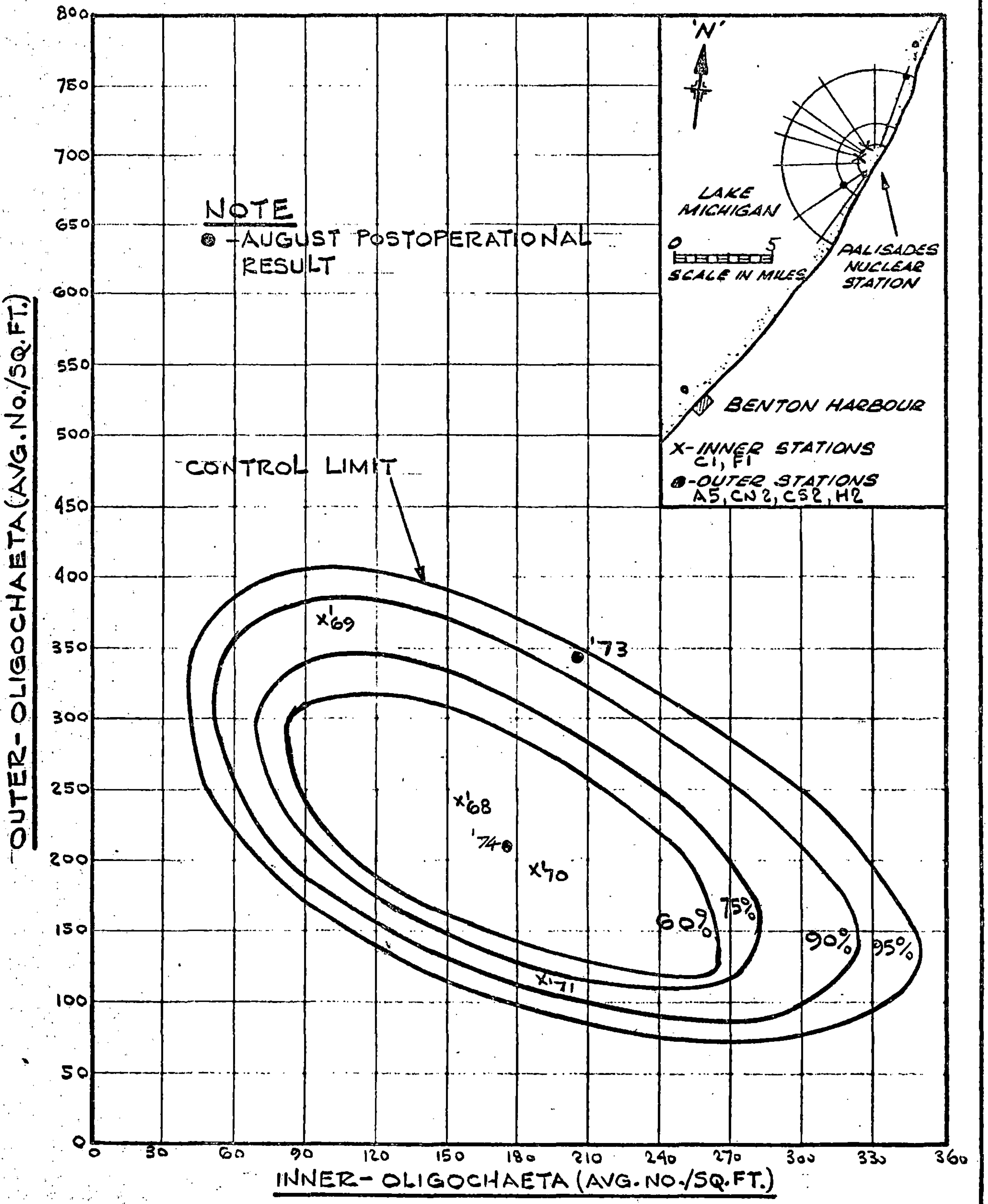
DENSITY OF SEGMENTED WORMS - SOUTH QUADRANT - DEPTH 20-30 FT.

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	9.13 BEAK	BY DATE 13·1·75 DWG NO A 2048 - 94	FIG. C-49A



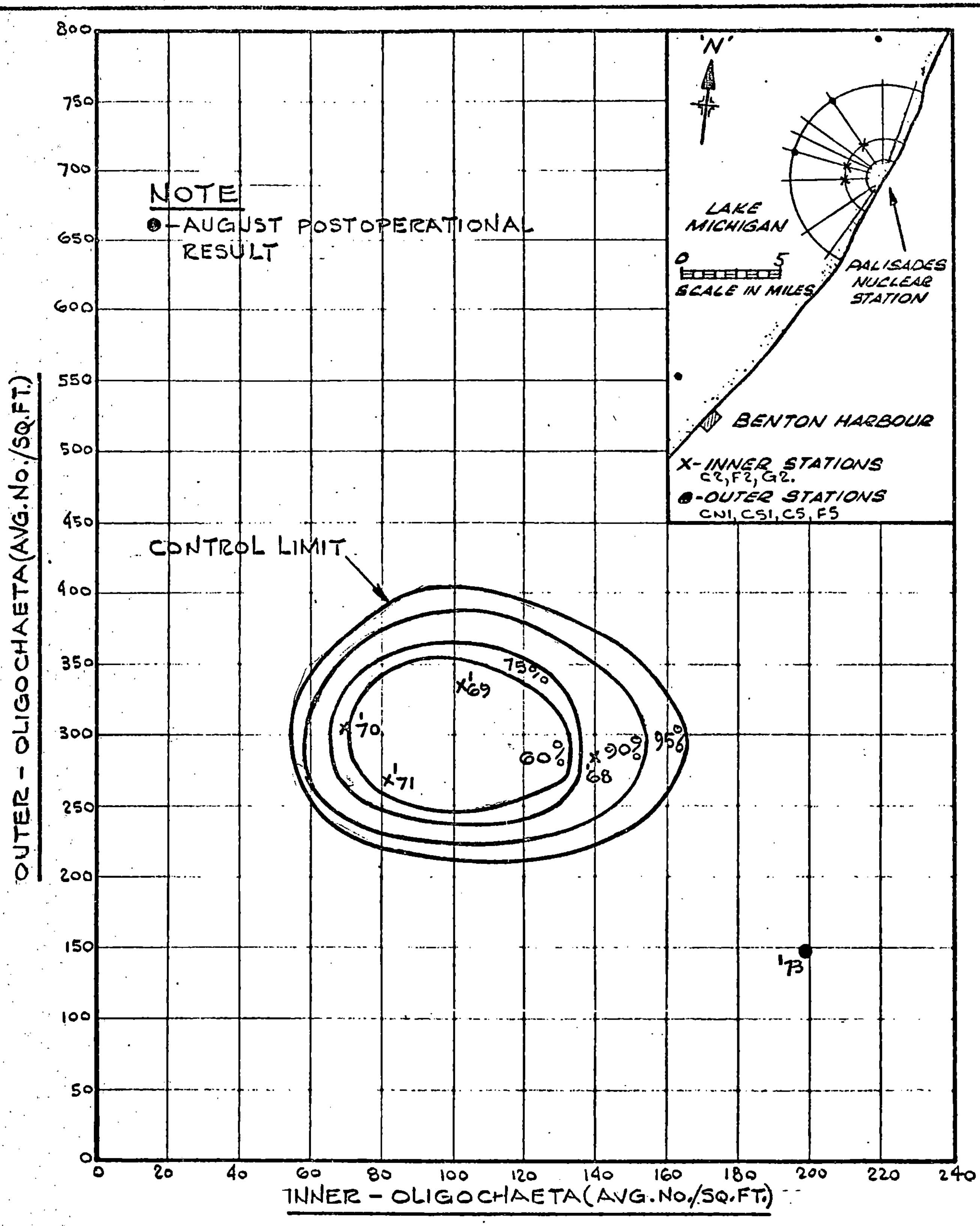
DENSITY OF SEGMENTED WORMS - DEPTH 30 - 50 FT.

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK 9.14	BY DATE 13·1·75 DWG NO A 2048 - 95	*FIG.* C-50A



DENSITY OF SEGMENTED WORMS - DEPTH GREATER THAN 50FT.

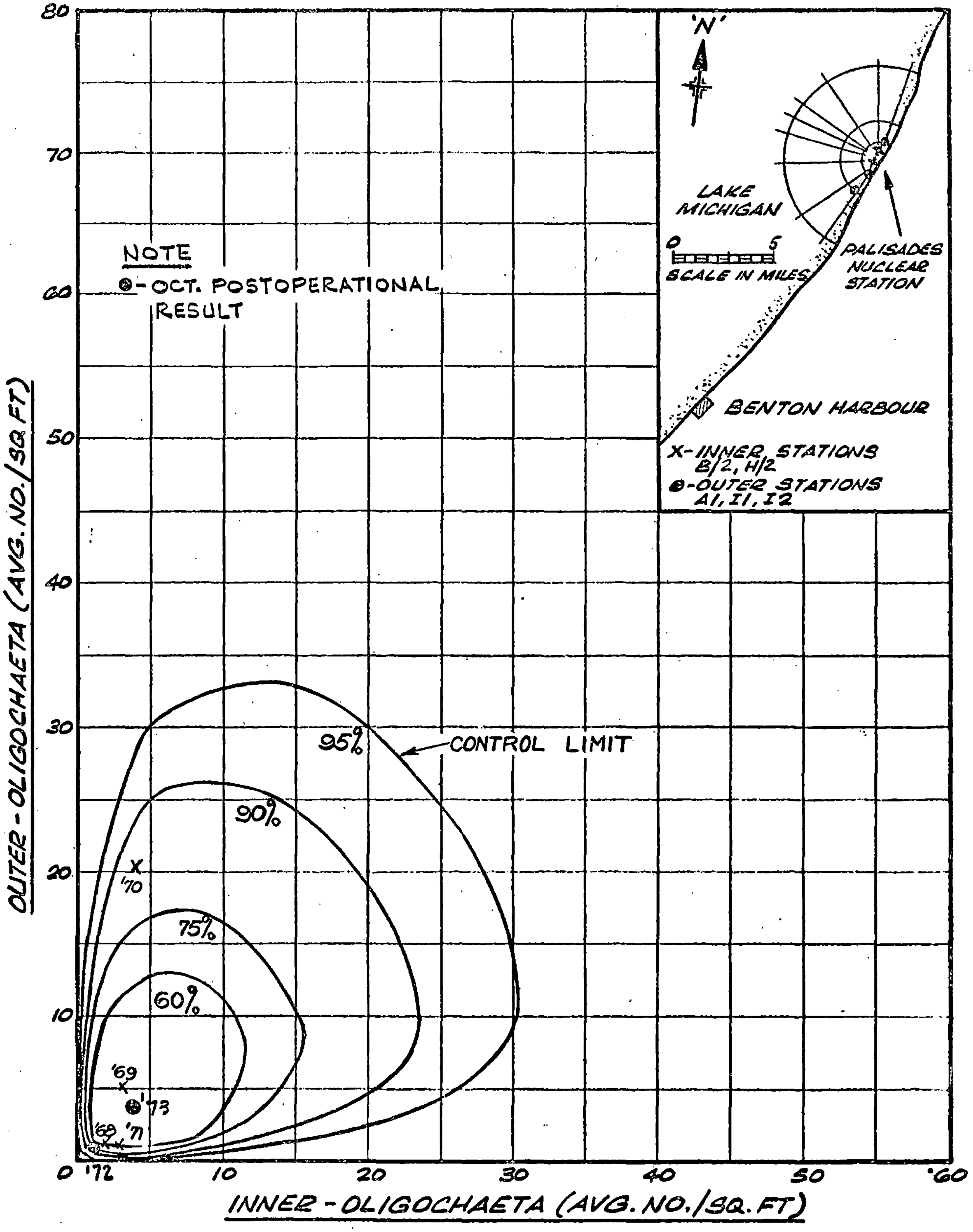
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY / DATE 17-10-73 DWG NO A 2048-96	*FIG.* C-51A

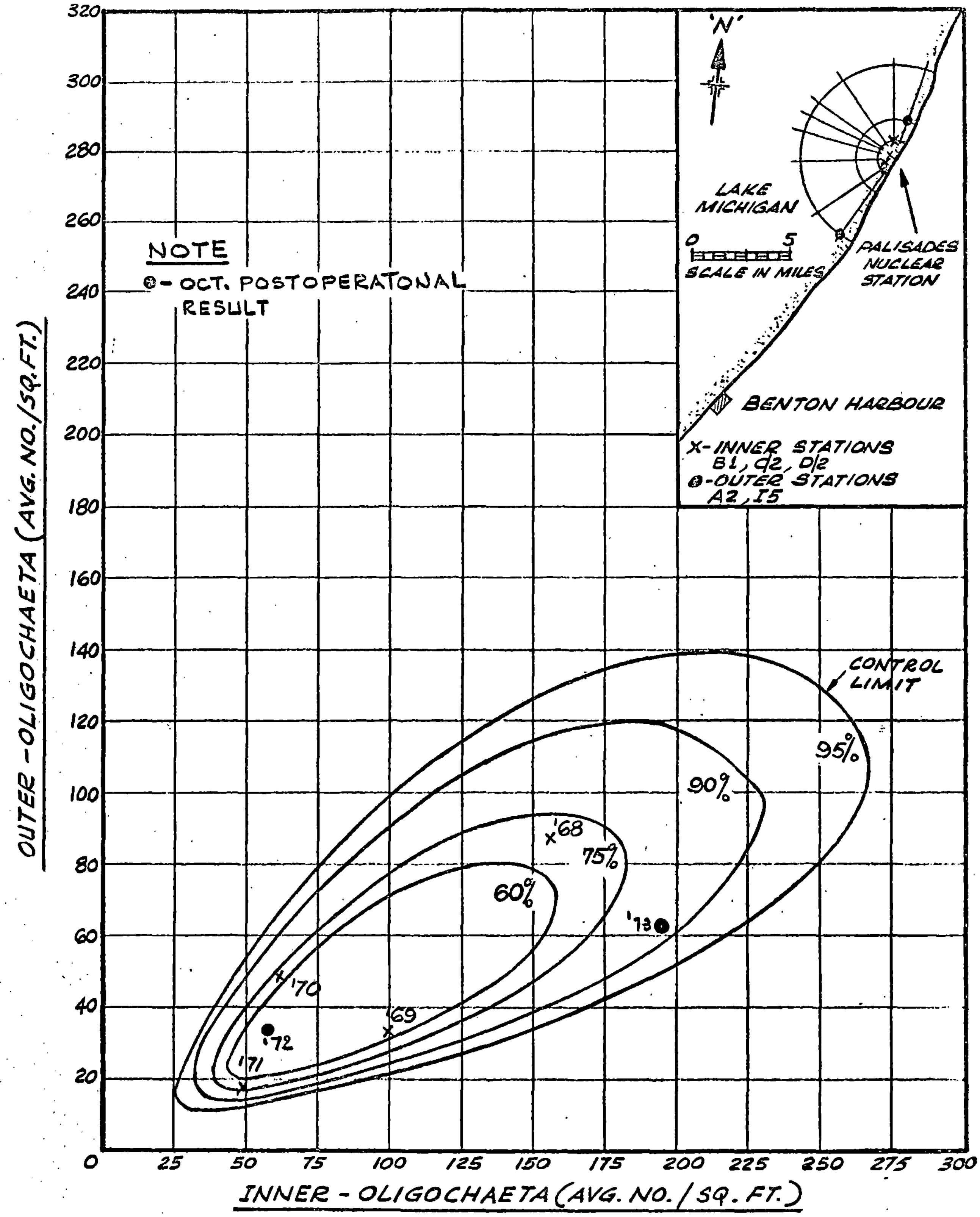
TRANSLAR 003



DENSITY OF SEGMENTED WORMS - DEPTH LESS THAN 20 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 15/73 DWG NO A 2048 - 40	FIG. C-52A

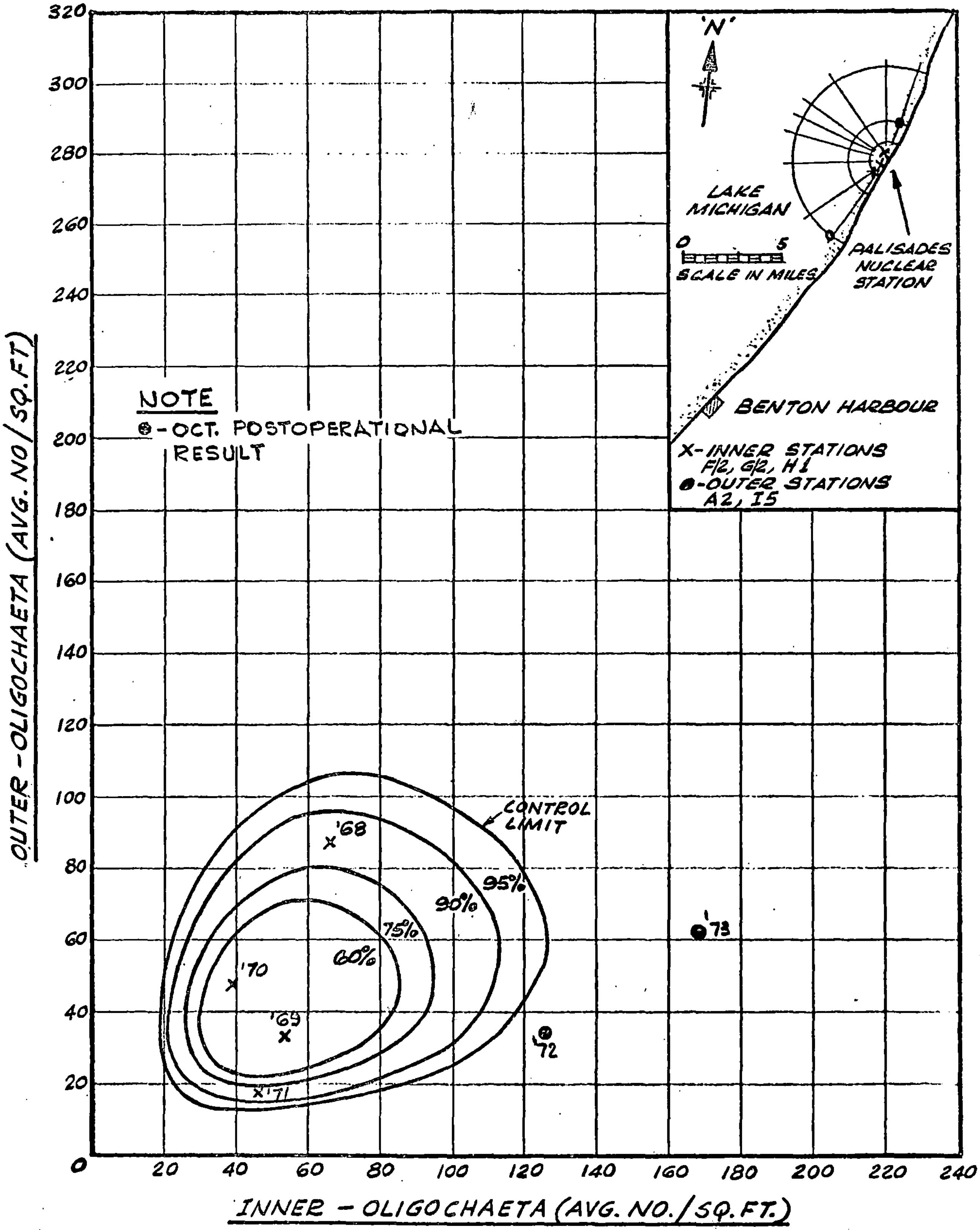
TRANSLAR 003



DENSITY OF SEGMENTED WORMS - NORTH QUADRANT - DEPTH 20-30 FT.
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY S. R. DATE JAN 15/73 DWG NO A 2048-41	FIG. C-53A

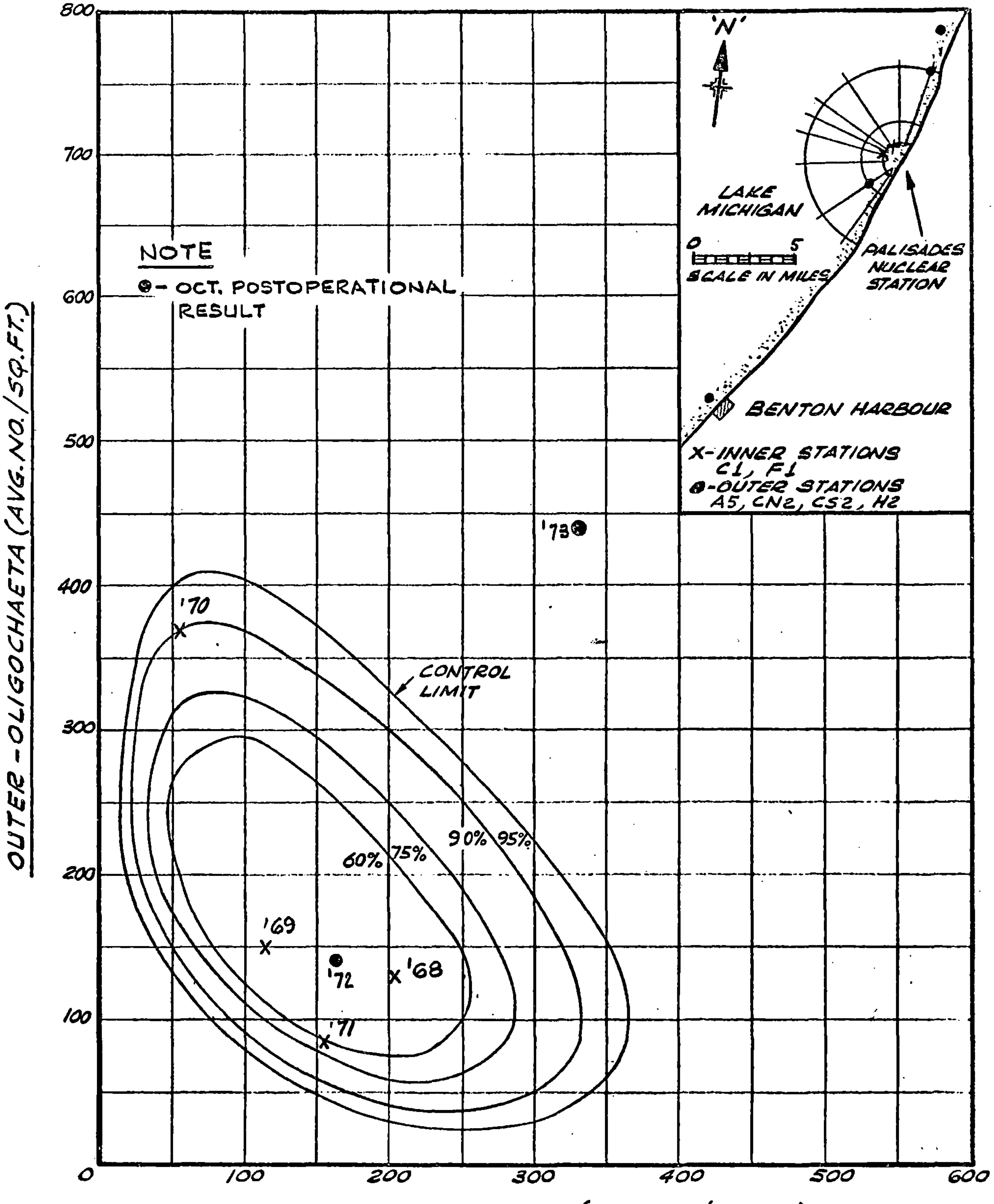
TRANSLAR 003



DENSITY OF SEGMENTED WORMS - SOUTH QUADRANT - DEPTH 20-30 FT.
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	5.17 BEAK	BY S.R. DATE JAN 15/73 DWG NO A 2048 - 42	FIG. C-54A

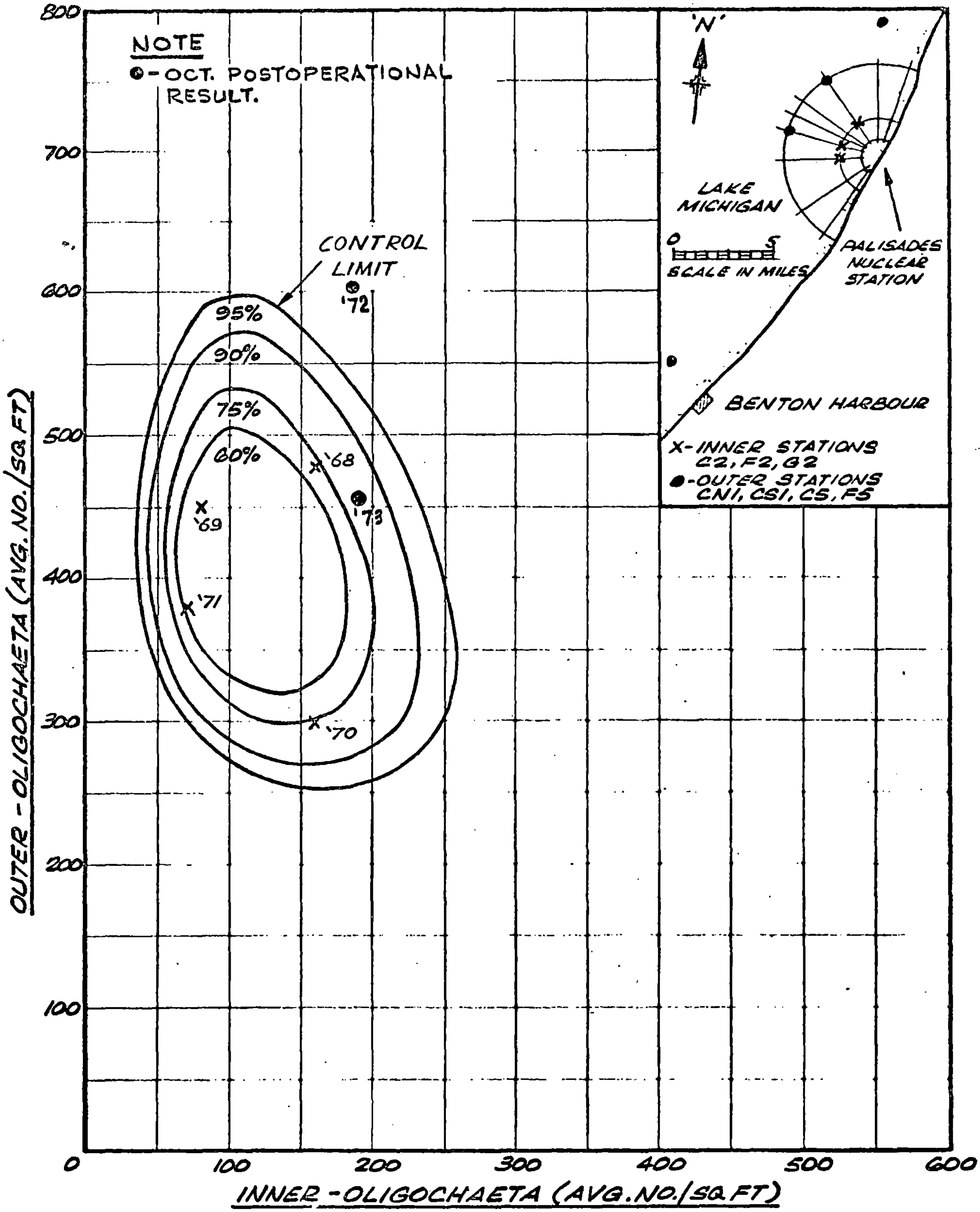
TRANSLAR 003



DENSITY OF SEGMENTED WORMS - DEPTH 30-50 FT.
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

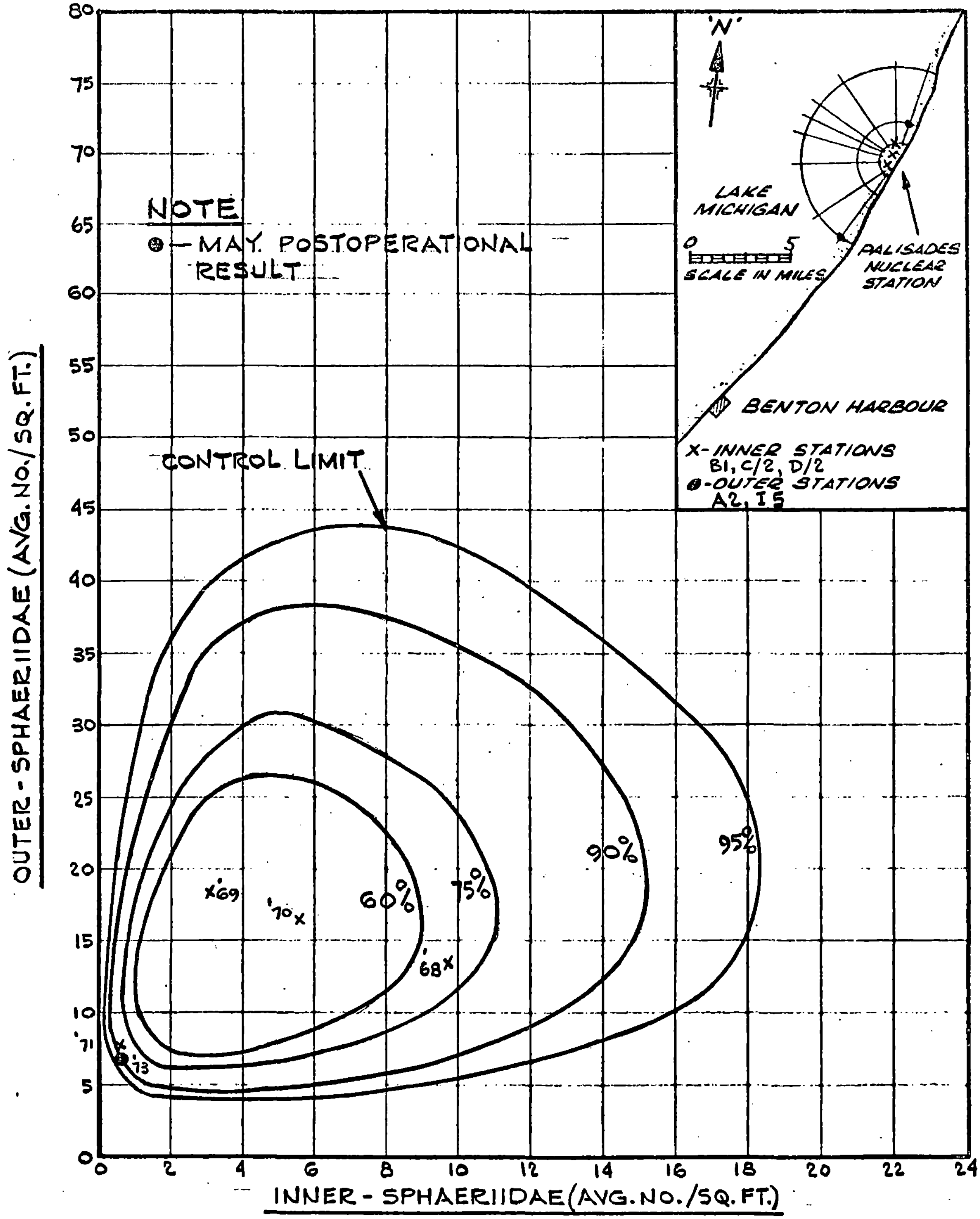
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	5.18 BEAK	BY S. R. DATE JAN 15/73 DWG NO A 2048 - 43	FIG. C-55A

TRANSLAR 003



DENSITY OF SEGMENTED WORMS - DEPTH GREATER THAN 50FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 15/73 DWG NO A 2048-44	FIG. C-56A



DENSITY OF FINGERNAIL CLAMS - NORTH QUADRANT - DEPTH 20-30 FT.

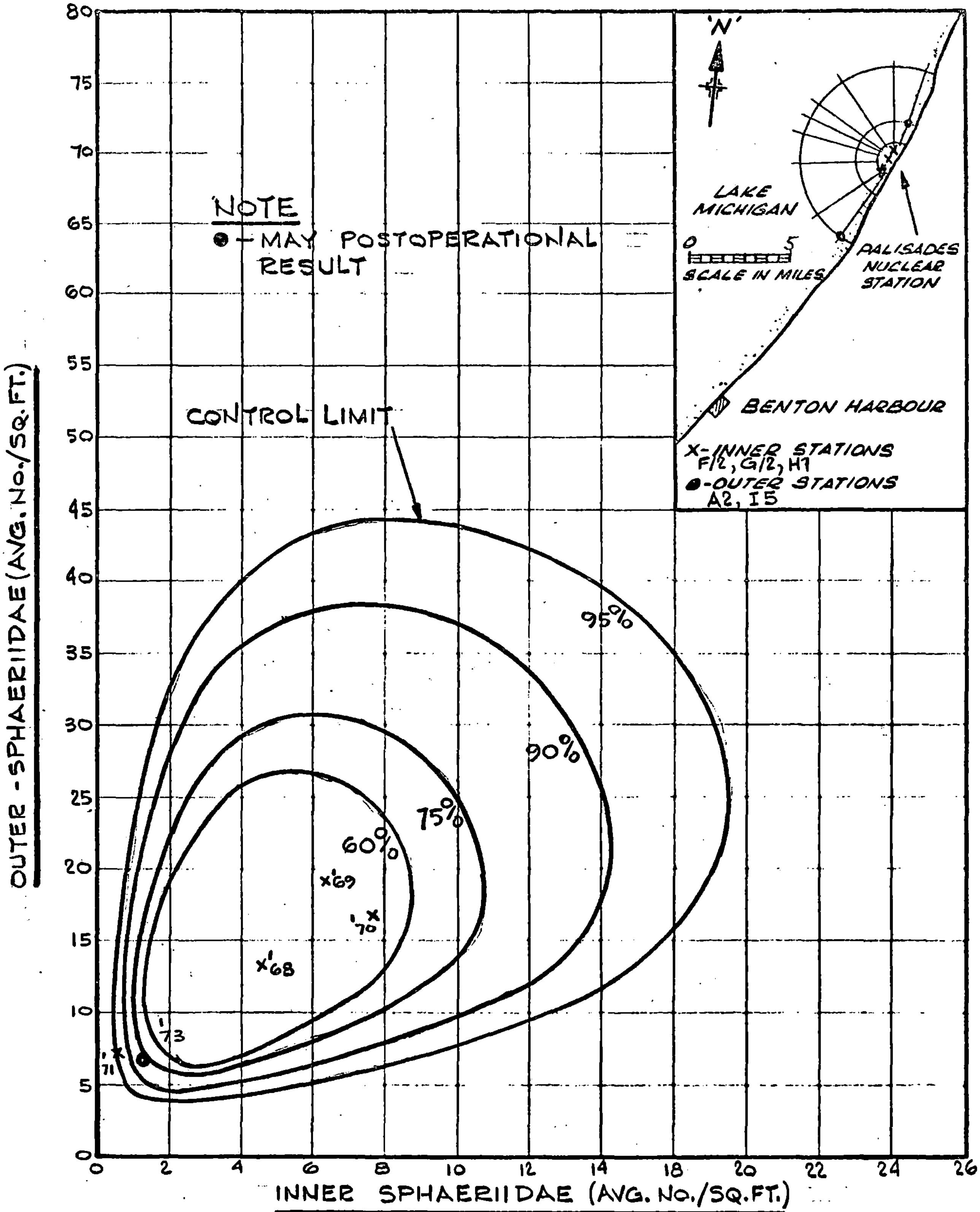
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY DATE 17-10-73 DWG NO A 2048-78	FIG. C-57A

TRANSLAR 003



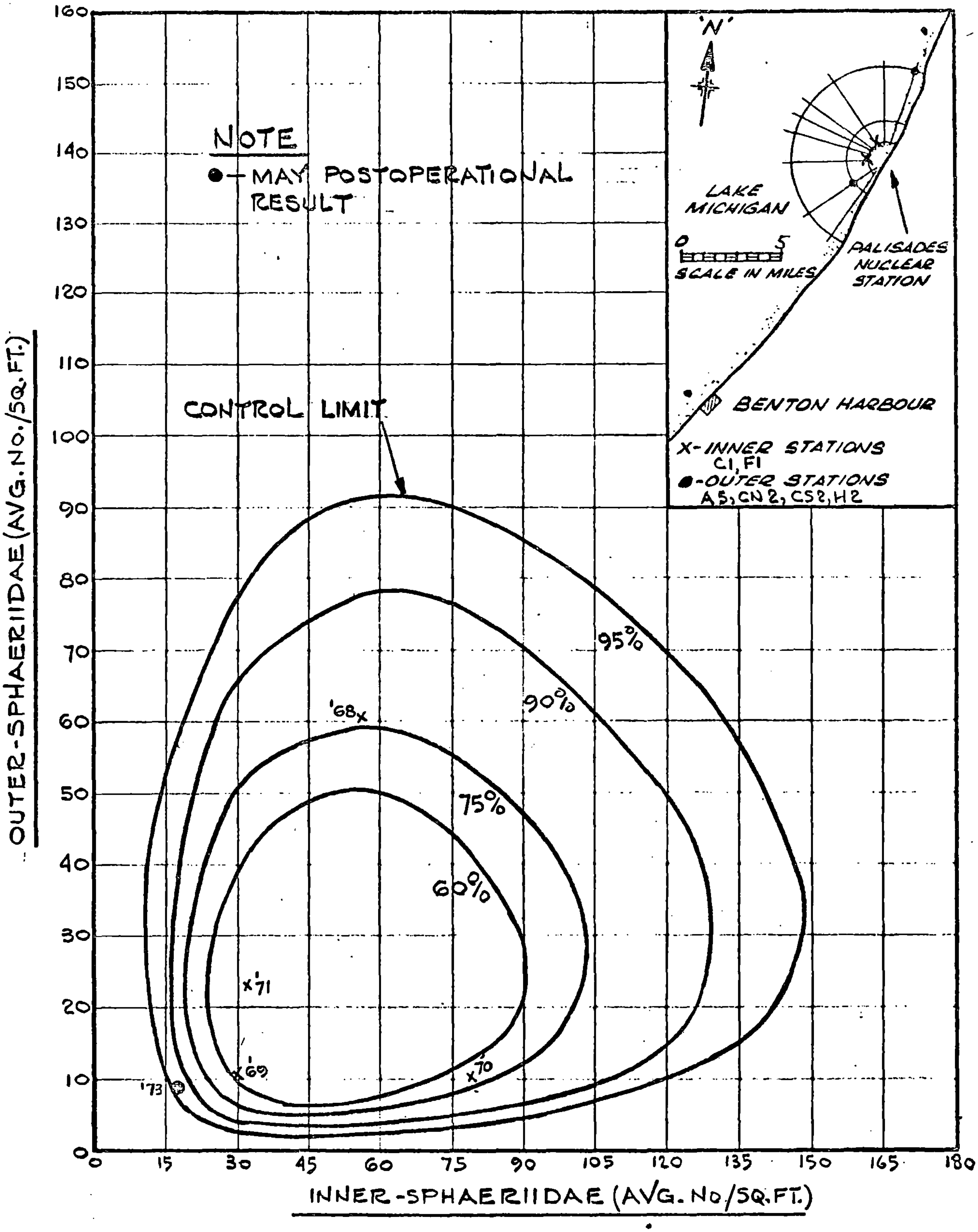
DENSITY OF FINGERNAIL CLAMS - SOUTH QUADRANT - DEPTH 20-30 FT.

MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY / DATE 17-10-73 DWG NO *A 2048 - 79*	*FIG.* C-58A



DENSITY OF FINGERNAIL CLAMS - DEPTH 30-50 FT.

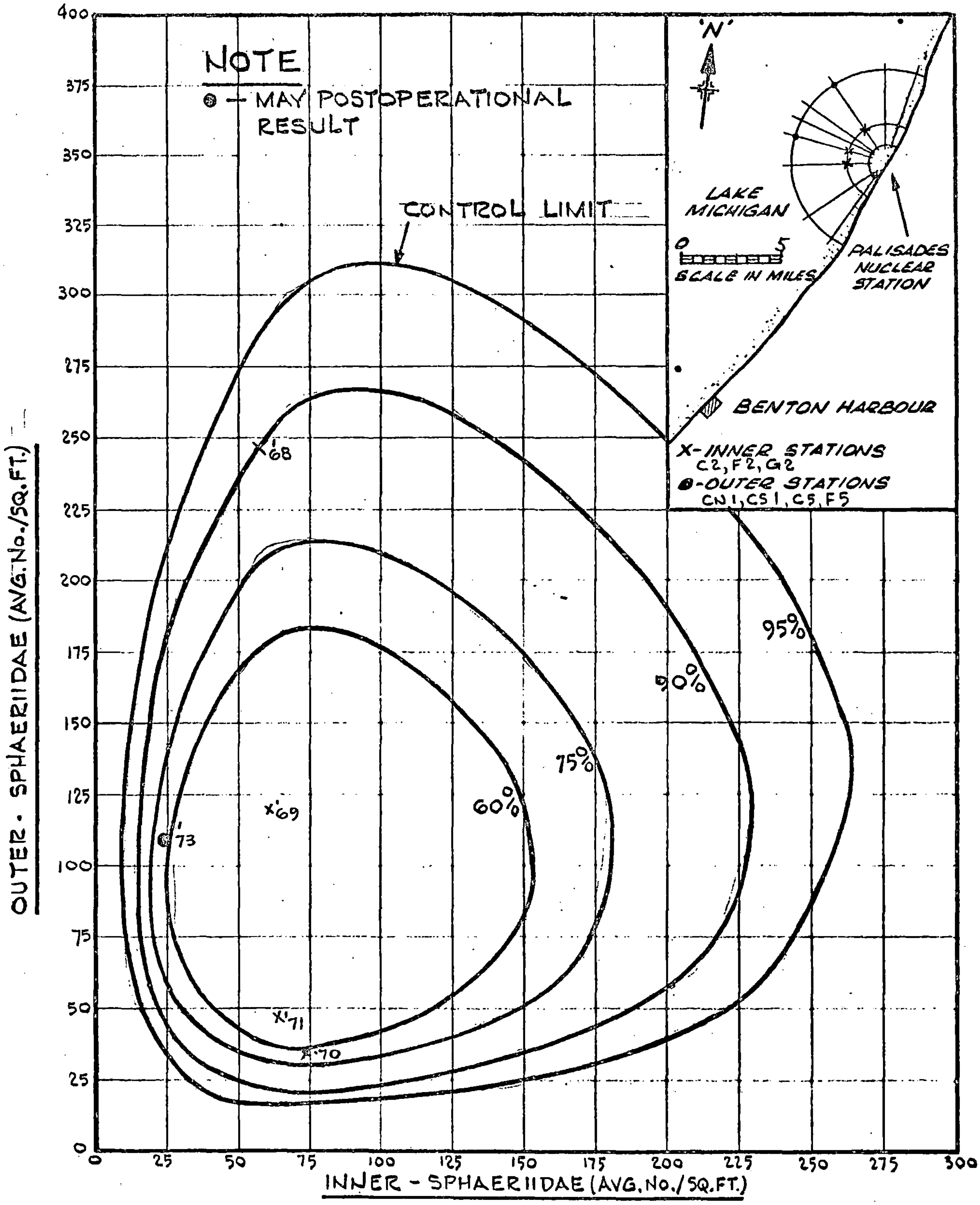
MAY BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY / DATE 17-10-73 DWG NO A 2048-80	FIG. C-59A

TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - DEPTH GREATER THAN 50 FT.

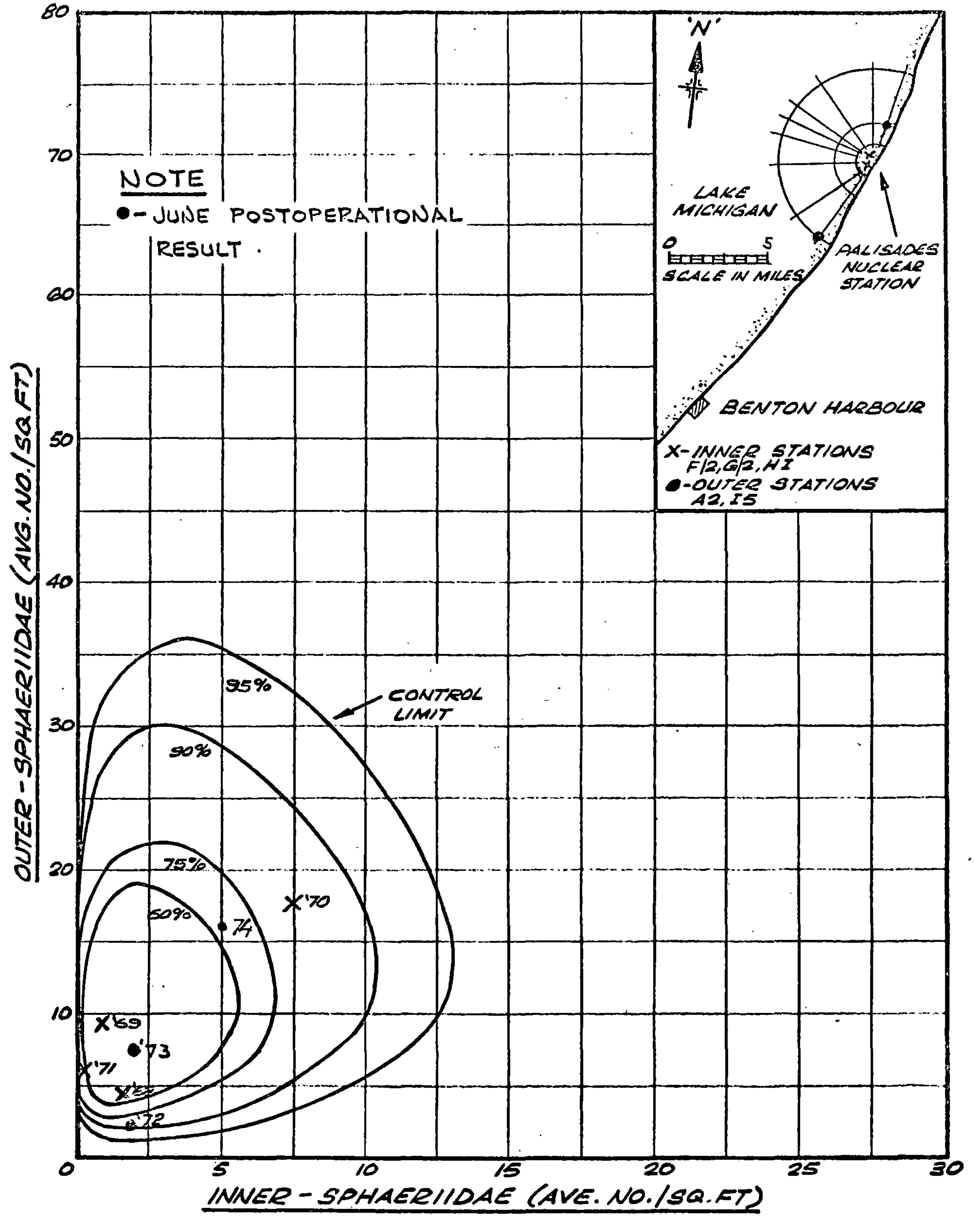
MAY *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY / DATE 17-10-73 / DWG NO A2048-81	FIG. C-60A

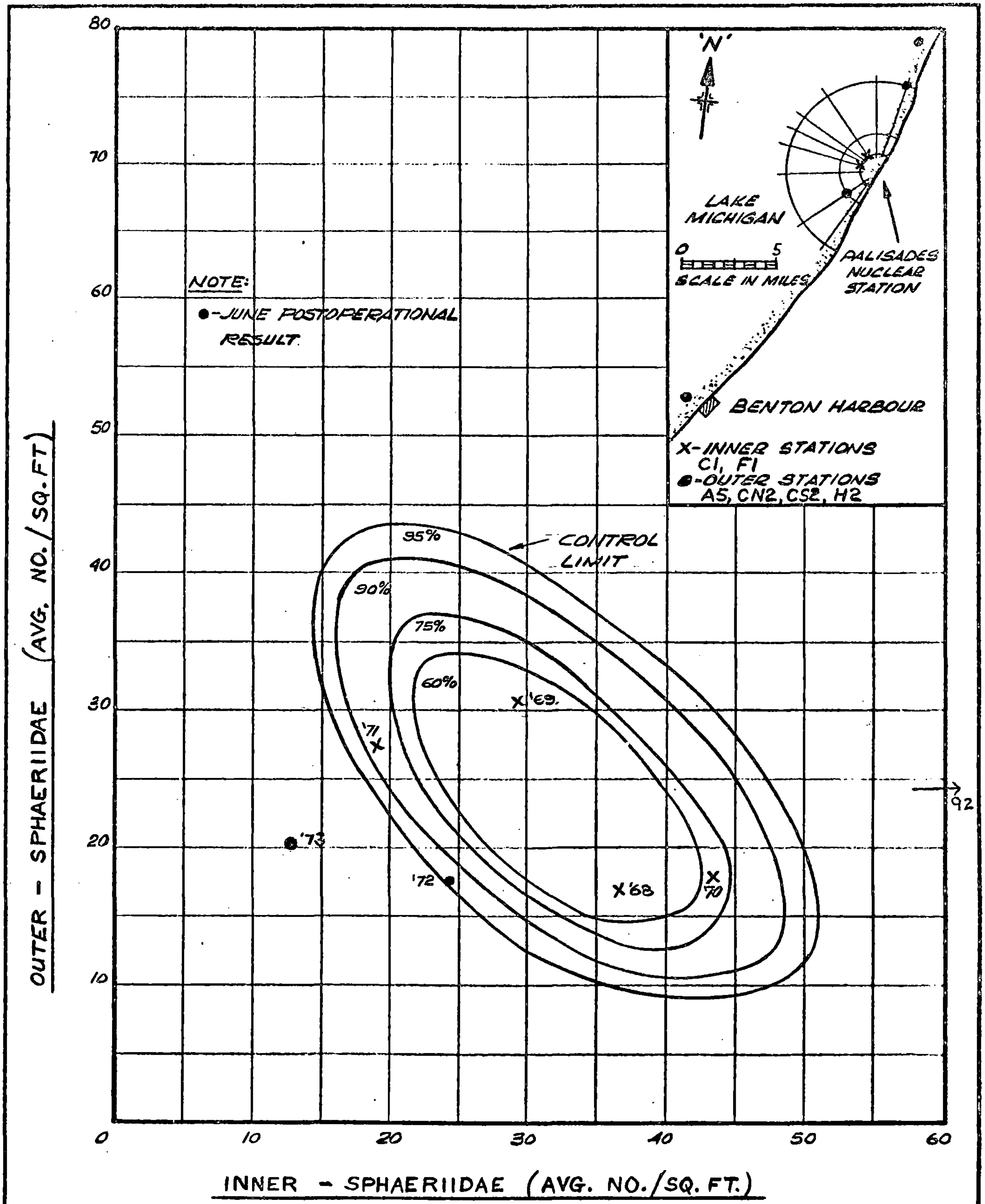
TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - SOUTH QUADRANT - DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	4.19 BEAK	BY RCD DATE 13.1.75 DWG NO A2048-24	FIG. C-61A

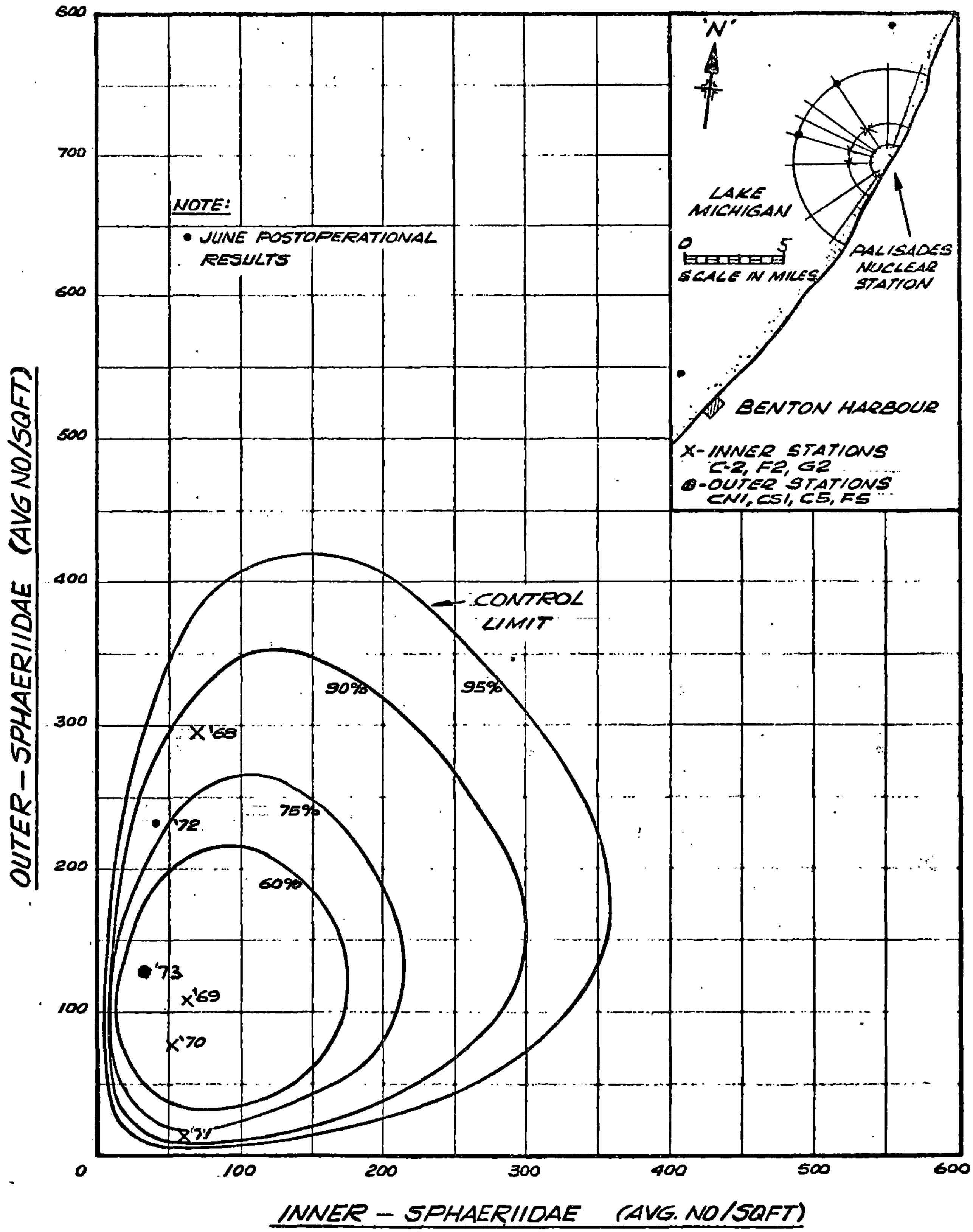
TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - DEPTH 30-50 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	4.20 BEAK	BY PR DATE 13.1.75 DWG NO A 2048 - 25	FIG. C-62A

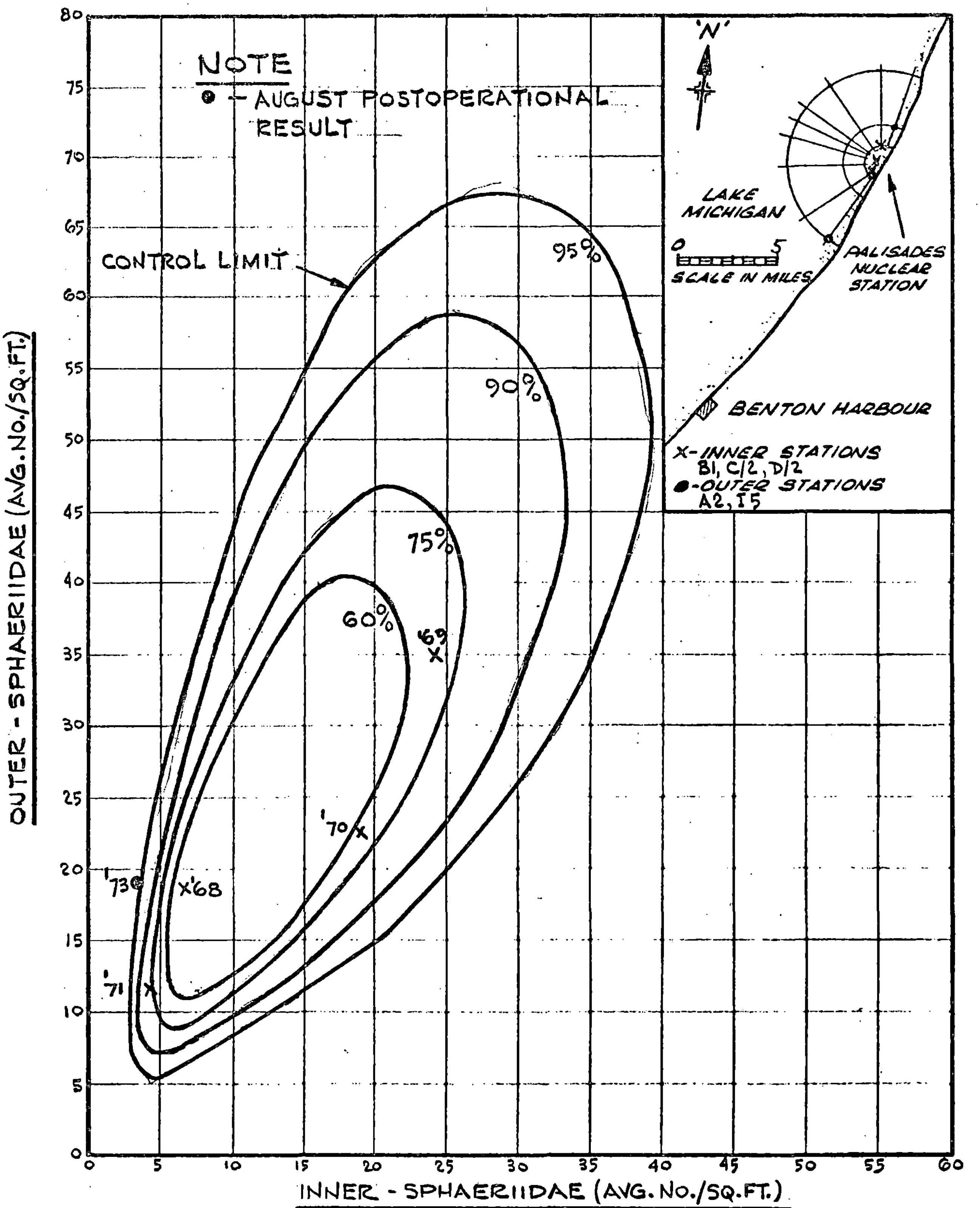
TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS — DEPTH GREATER THAN 50FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON – MICHIGAN	BEAK	BY PAC DATE 1 AUG 73 DWG NO A 2048-61	FIG. C-63A

TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - NORTH QUADRANT - DEPTH 20-30 FT.

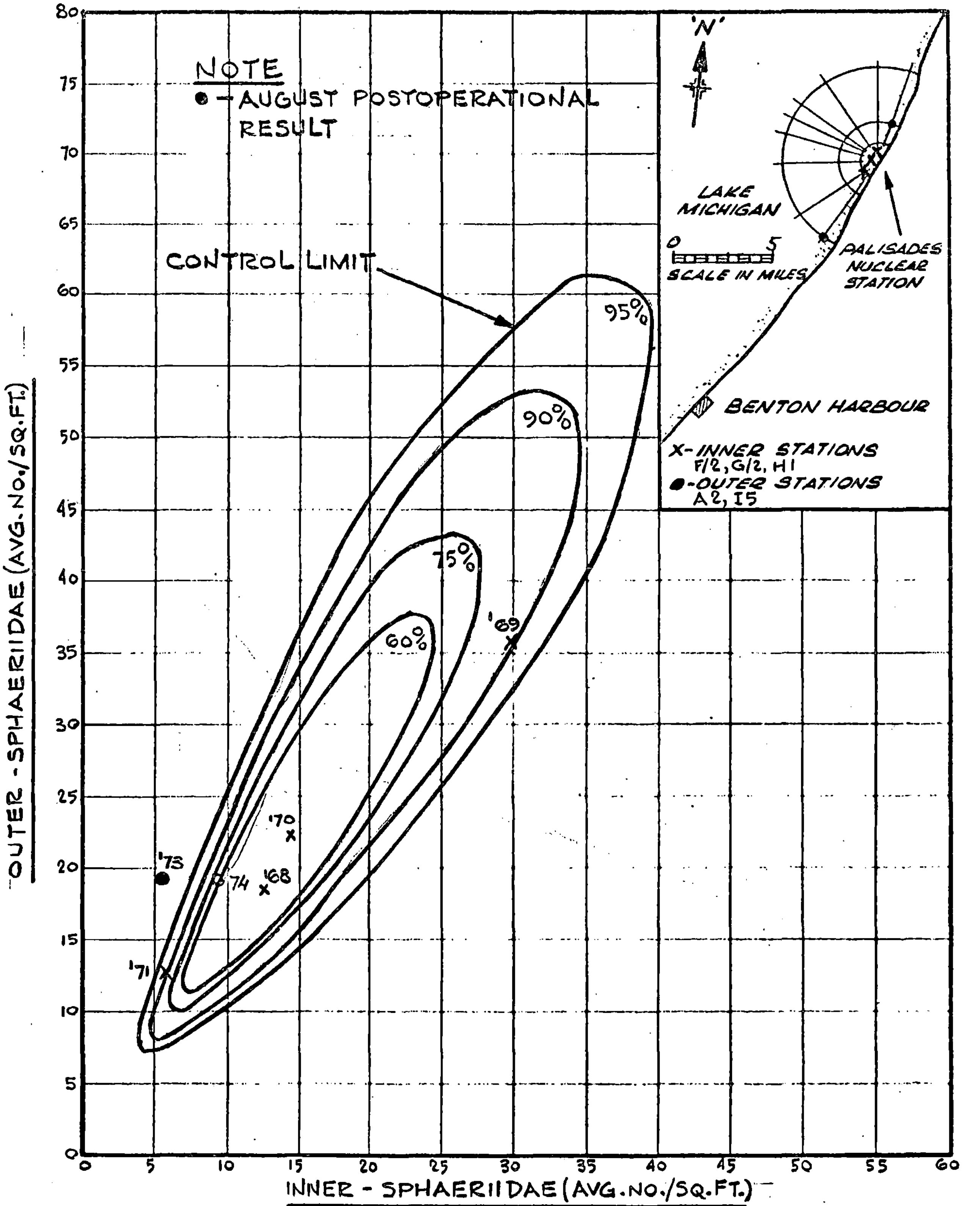
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY DATE 17-10-73 DWG NO *A 2048 - 97*	*FIG.* C-64A

TRANSLAR 003



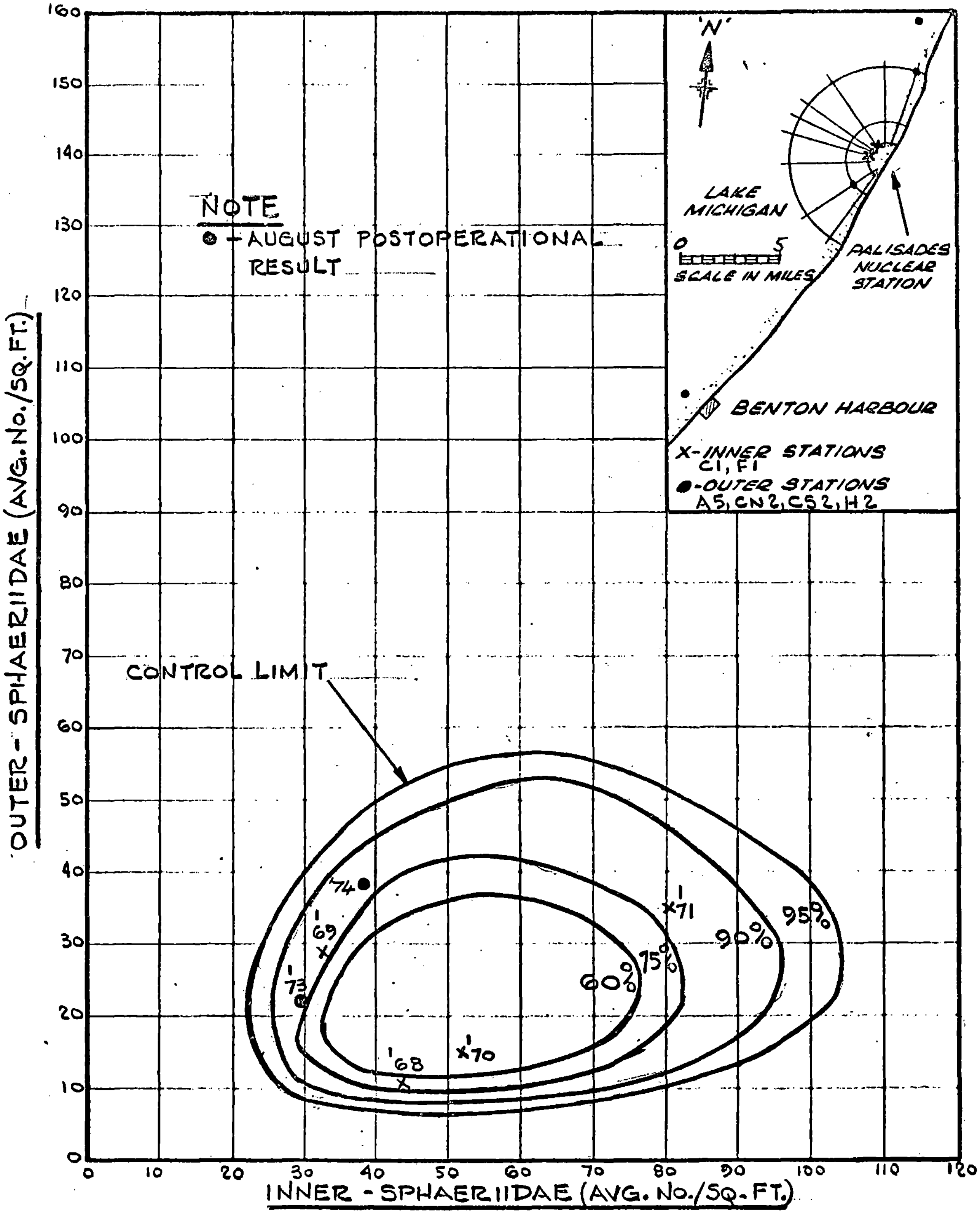
DENSITY OF FINGERNAIL CLAMS - SOUTH QUADRANT - DEPTH 20-30 FT.

AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON – MICHIGAN*	9.17 BEAK	BY DATE 13.1.75 DWG NO A 2048 - 98	FIG. C-65A



DENSITY OF FINGERNAIL CLAMS - DEPTH 30 - 50 FT.

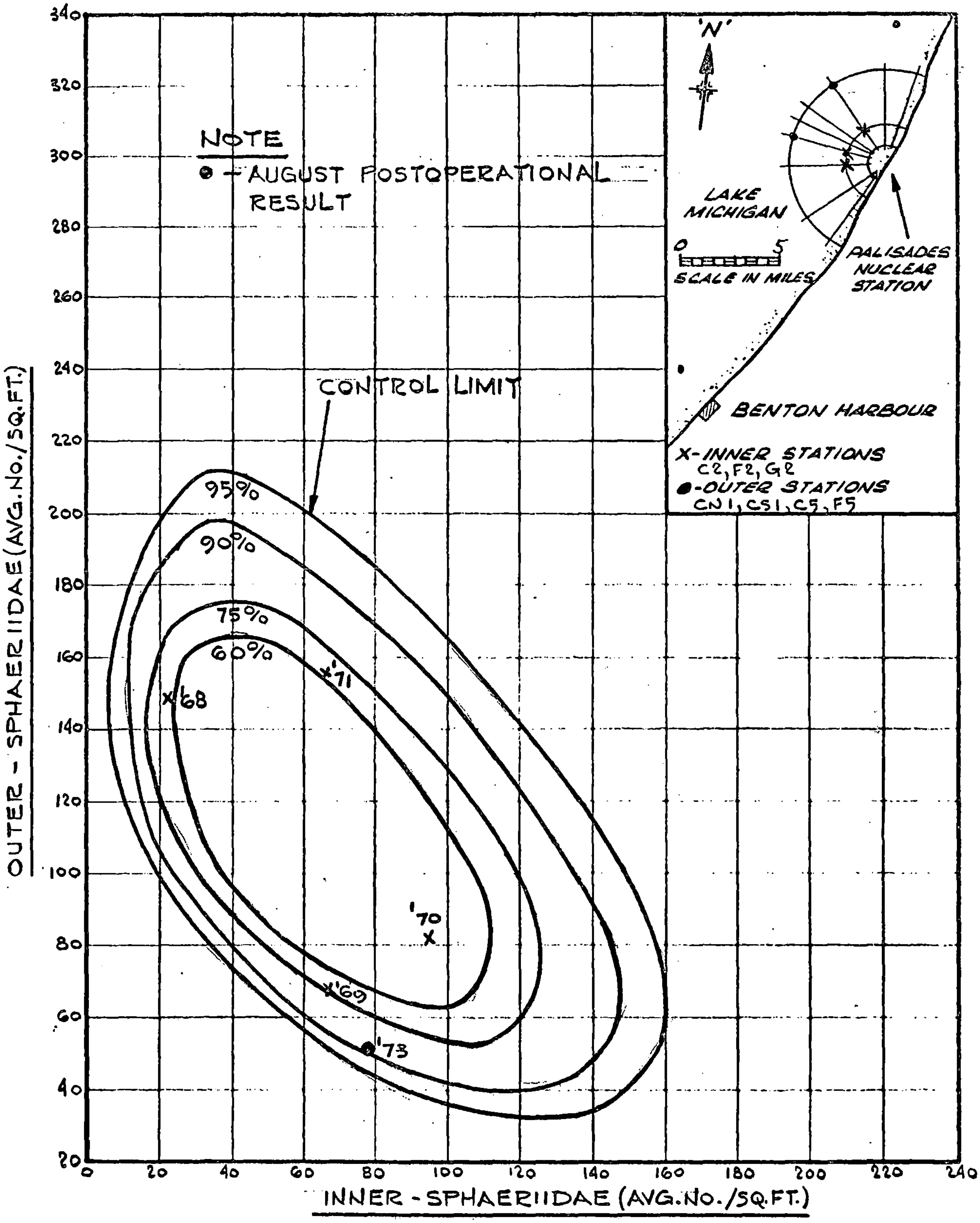
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	9.18 BEAK	BY DATE 13.1.75 DWG NO A2048-99	FIG. C-66A

TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - DEPTH GREATER THAN 50FT.

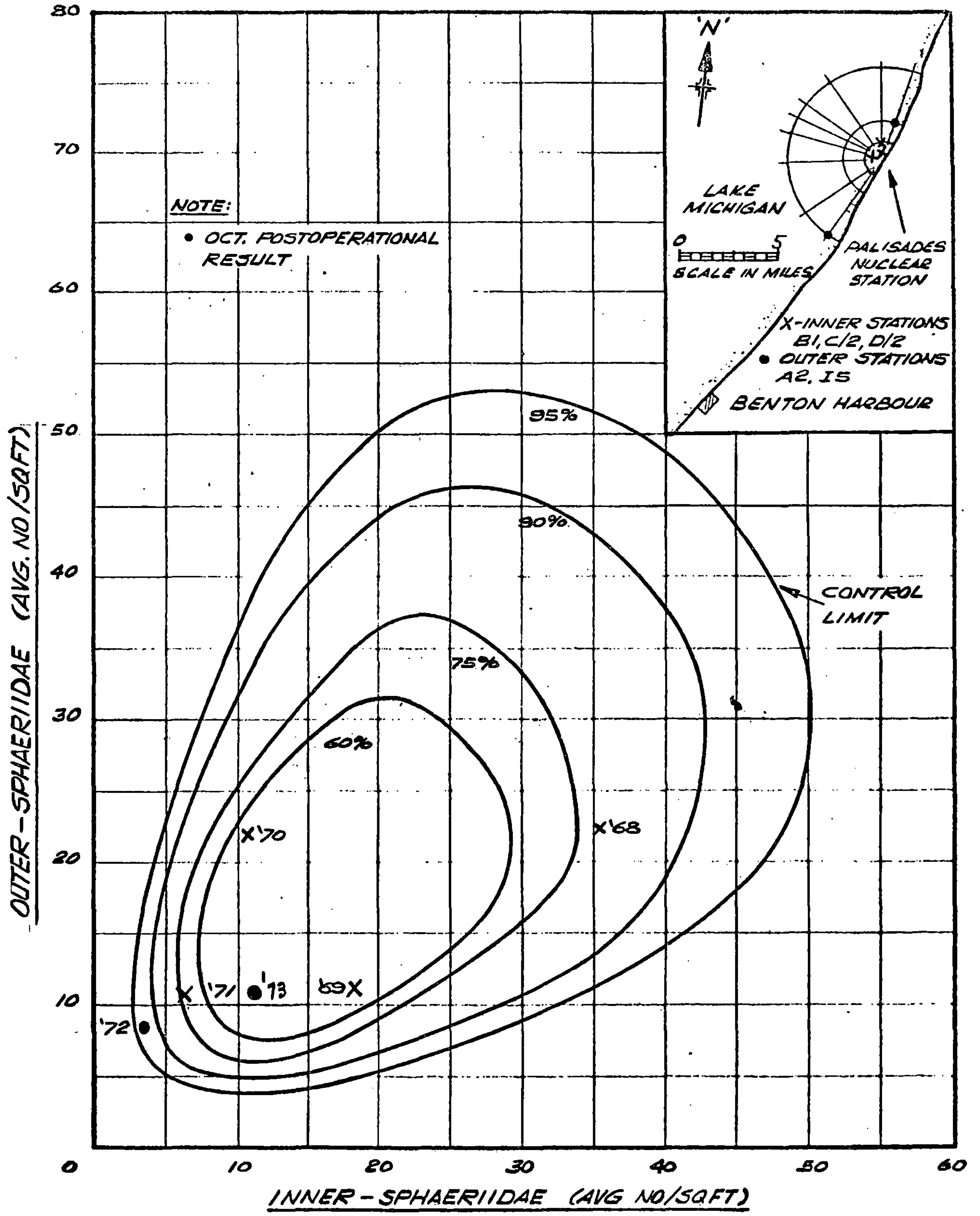
AUGUST *BIVARIATE CONTROL CHART*

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY *JACKSON - MICHIGAN*	BEAK	BY / DATE 17-10-73 DWG NO A2048-100	*FIG.* C-67A

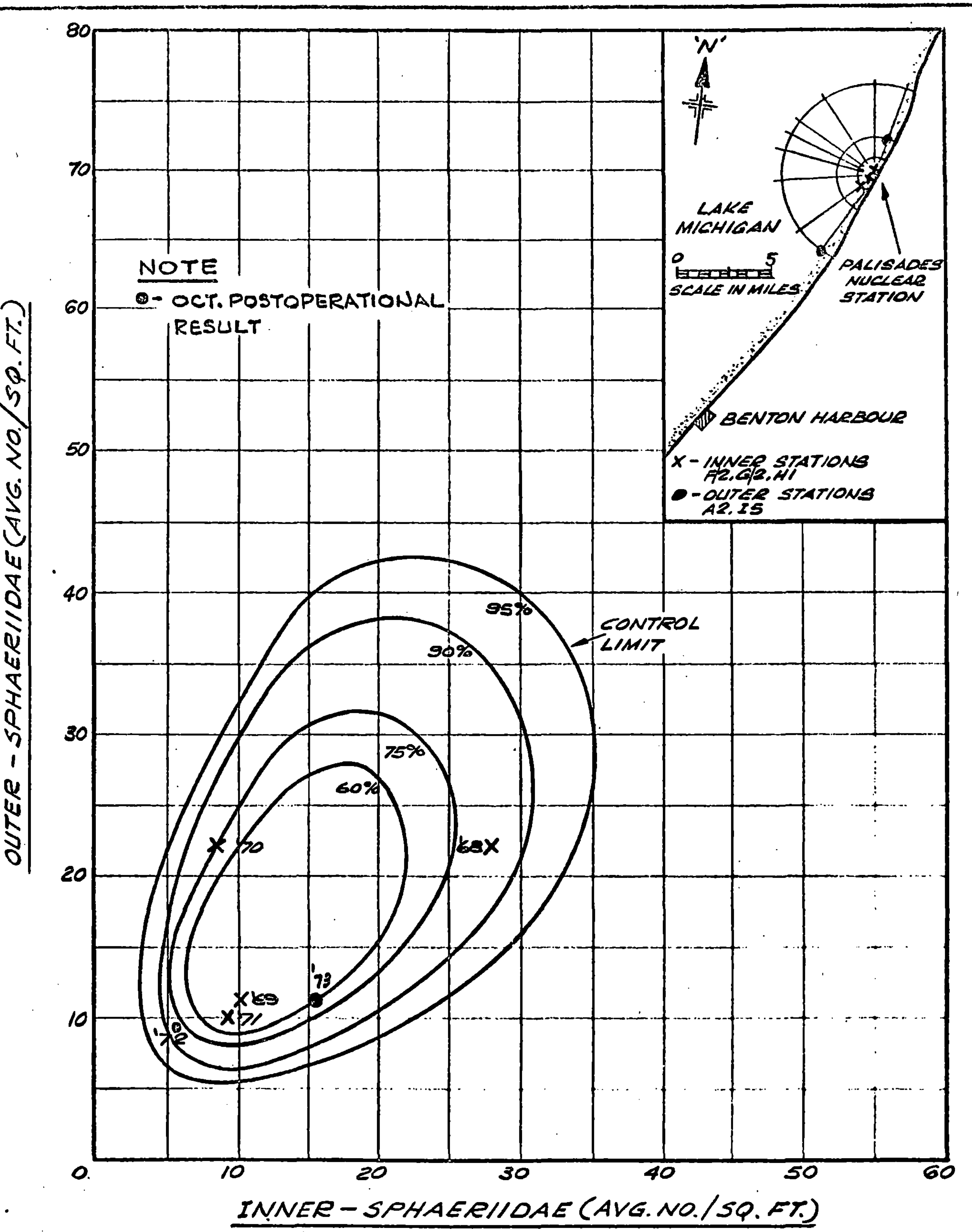
TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - NORTH QUADRANT - DEPTH 20-30 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 5.20	BY PAC DATE 1 AUG '73 DWG NO A 2048-45	FIG. C-68A

TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - SOUTH QUADRANT - DEPTH 20-30 FT

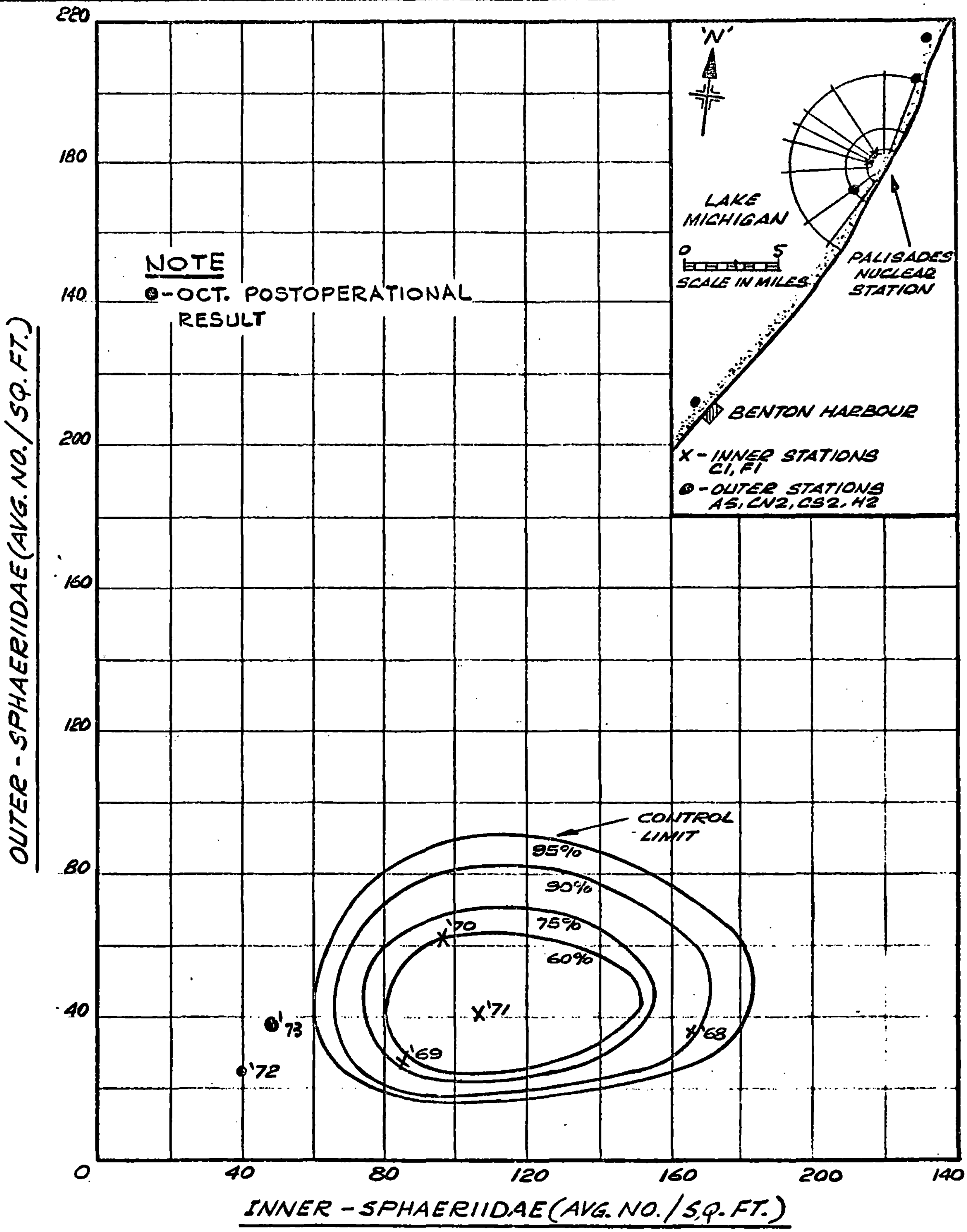
OCTOBER BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY S. R. DATE JAN 16/73 DWG. NO A 2048-46	FIG. C-69A

TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - DEPTH 30-50 FT

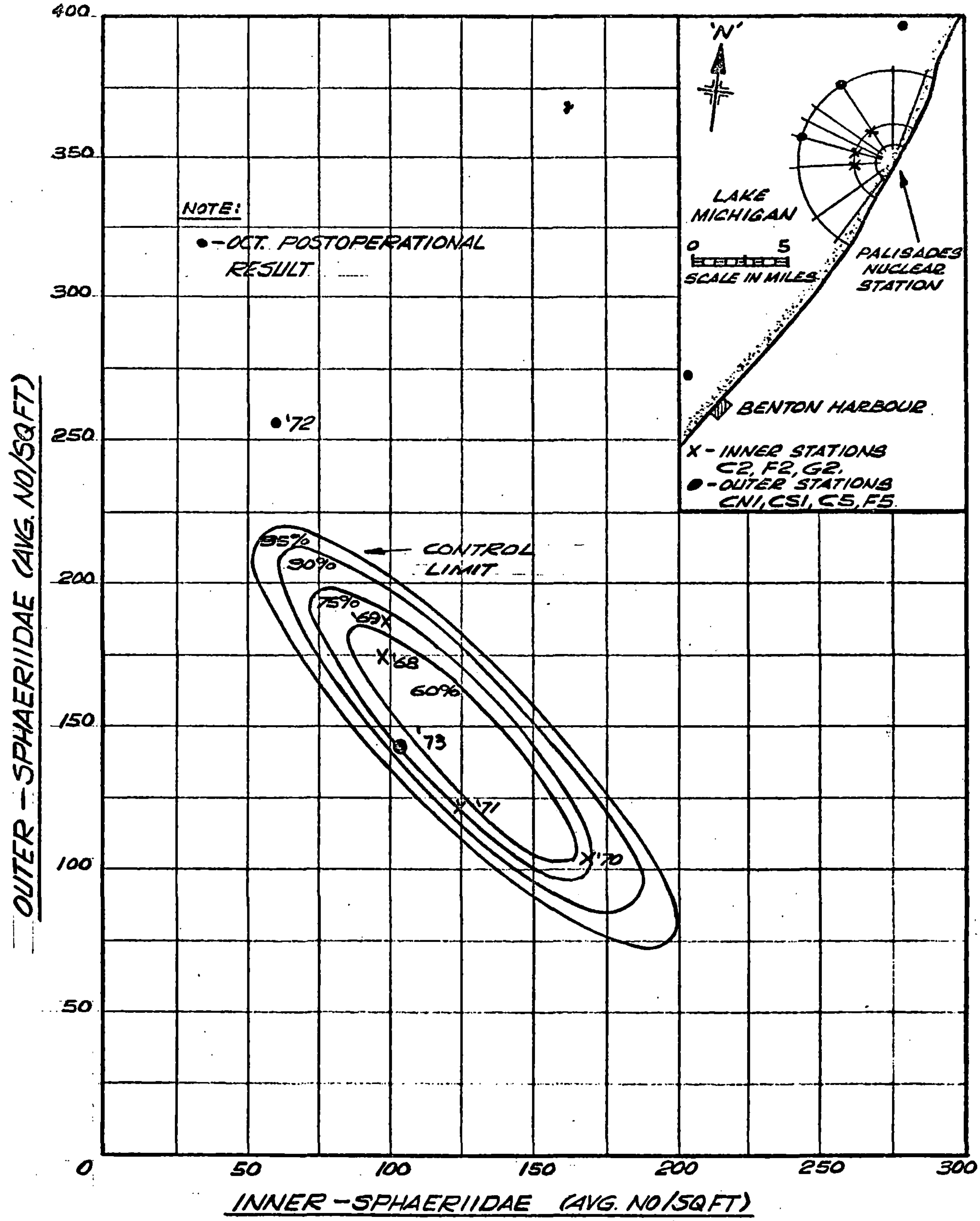
OCTOBER BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	S.22 BEAK	BY S. R. DATE JAN 16/73 DWG NO A 2048-47	FIG. C-70A

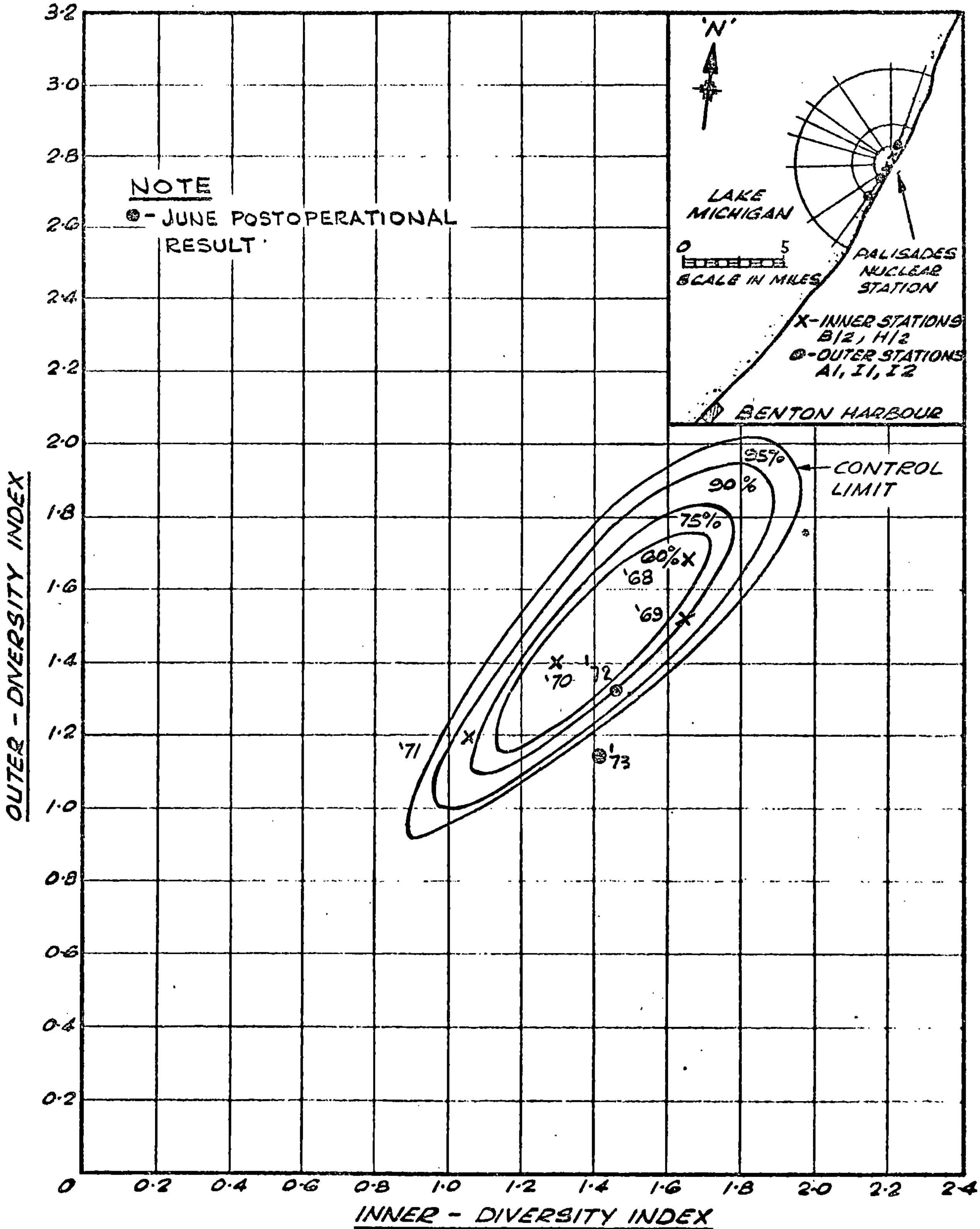
TRANSLAR 003



DENSITY OF FINGERNAIL CLAMS - DEPTH GREATER THAN 50 FT.
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

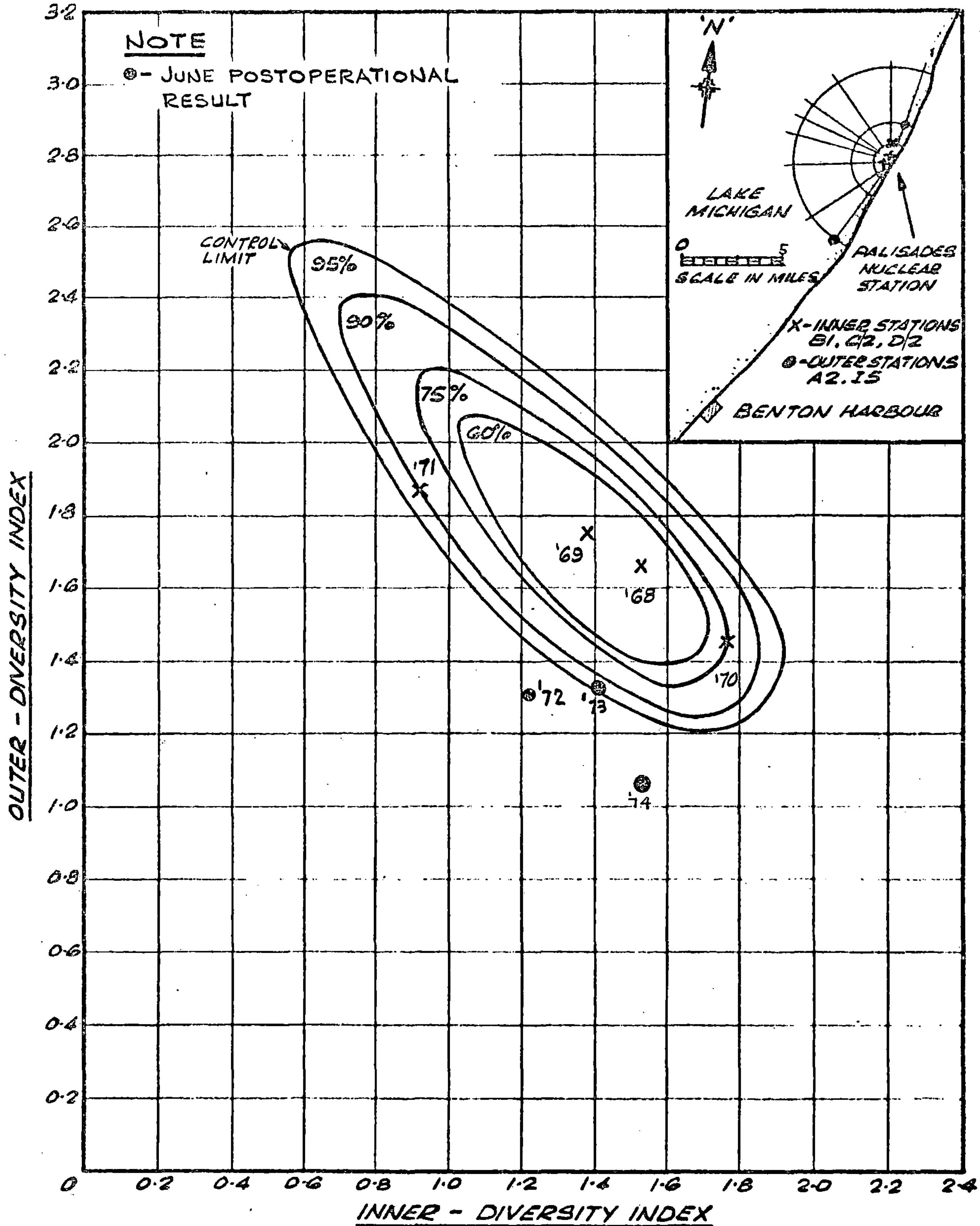
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY FAC DATE 2AUG73 DWG NO A 2048-48	FIG. C-71A

TRANSLAR 003



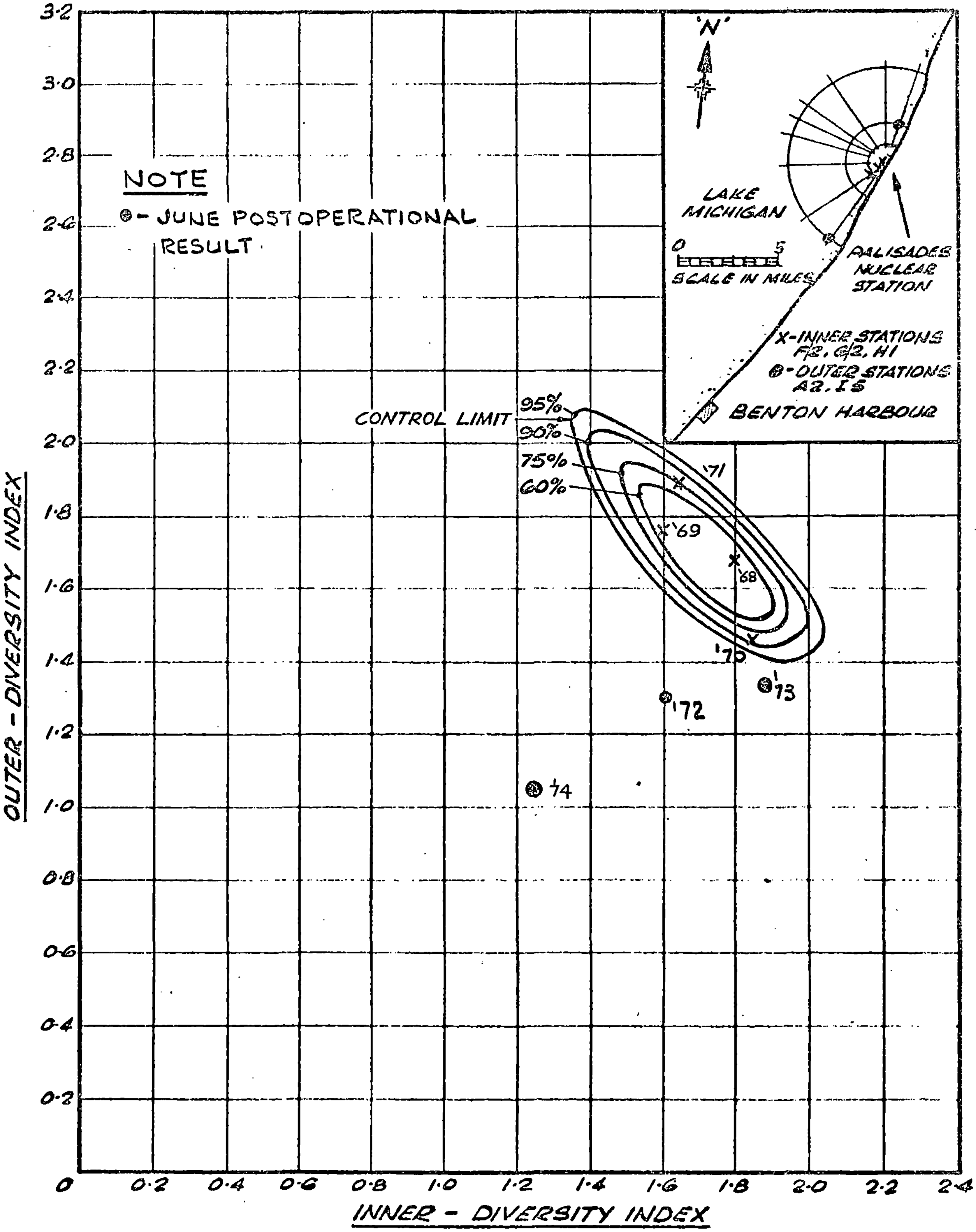
BENTHOS DIVERSITY-DEPTH LESS THAN 20FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 14/73 DWG NO A 2048 - 6	FIG. C-72A



BENTHOS DIVERSITY - NORTH QUADRANT - DEPTH 20-30 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 4.2	BY RCD DATE JAN 6/75 DWG NO A 2048 - 7	FIG. C-73A



BENTHOS DIVERSITY - SOUTH QUADRANT - DEPTH 20-30 FT

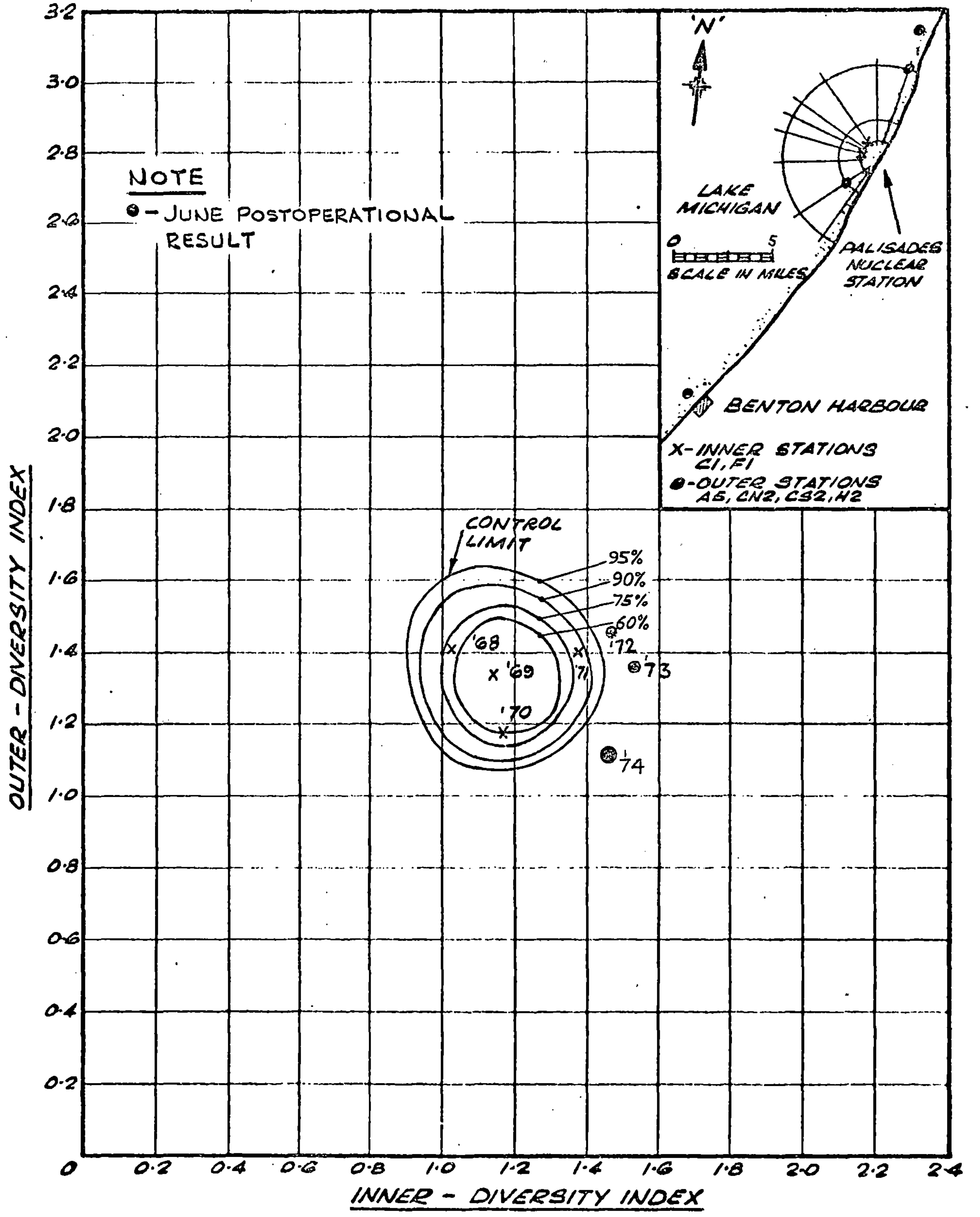
JUNE BIVARIATE CONTROL CHART

PREOPERATIONAL PERIOD 1968-71

LAKE MICHIGAN NEAR PALISADES, MICHIGAN

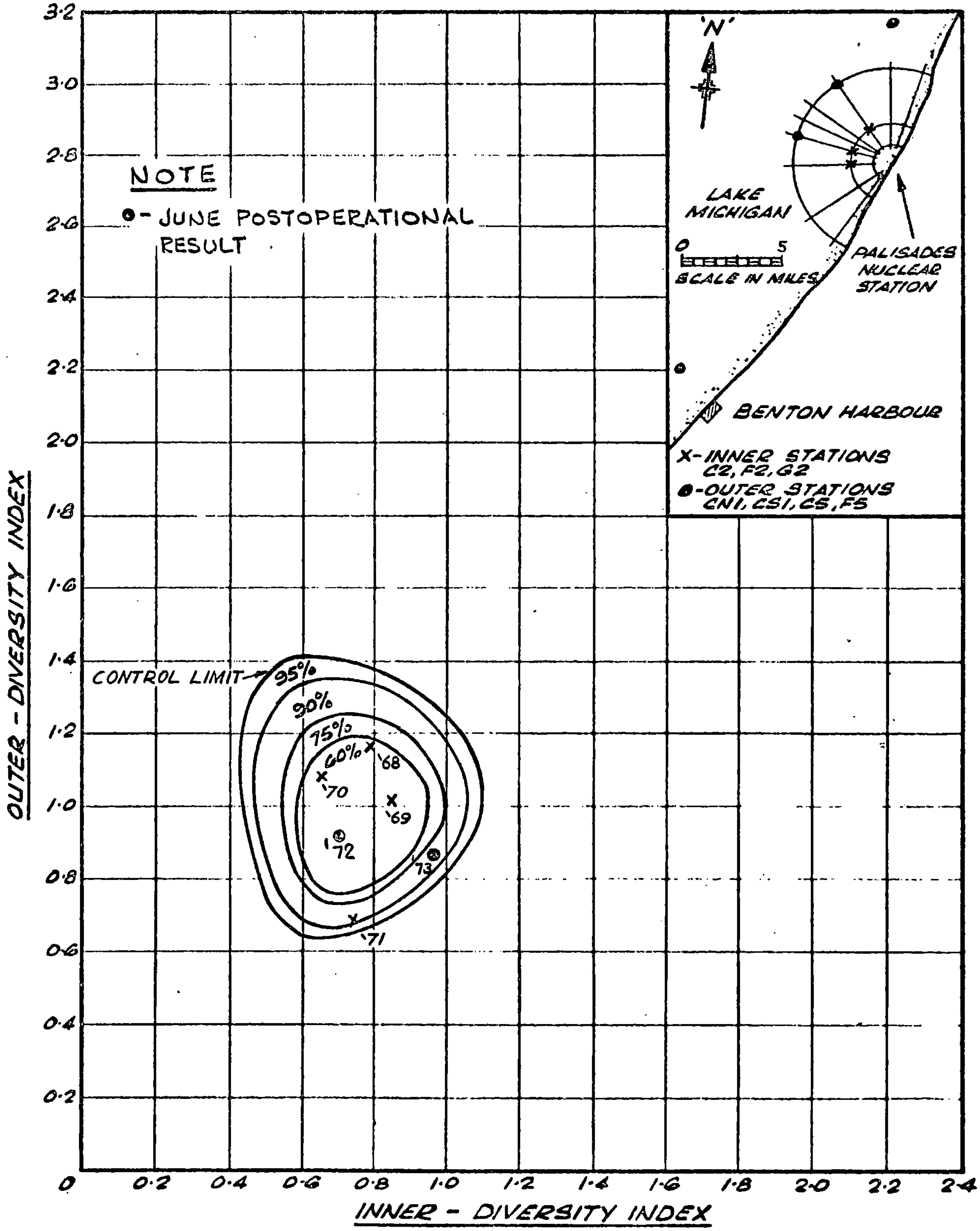
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	4.3 BEAK	BY RCD DATE JAN 6 /75 DWG NO A 2048 - 8	FIG. C-74A

TRANSLAR 003



BENTHOS DIVERSITY-DEPTH 30-50 FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

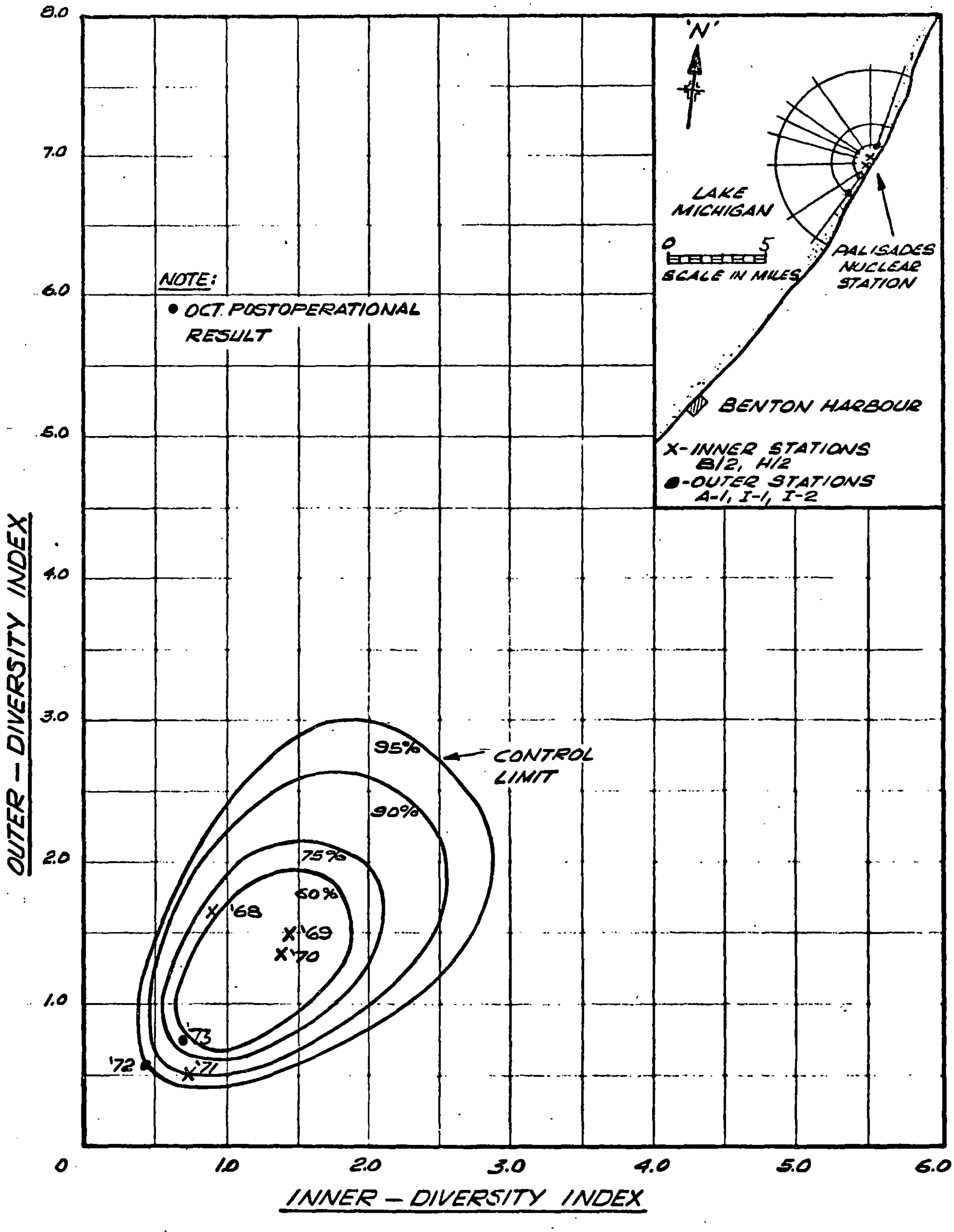
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK 4.4	BY RCD	DATE JAN 6 /75	FIG. C-75A
		DWG NO A 2048 - 9		



BENTHOS DIVERSITY - DEPTH GREATER THAN 50FT
JUNE BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

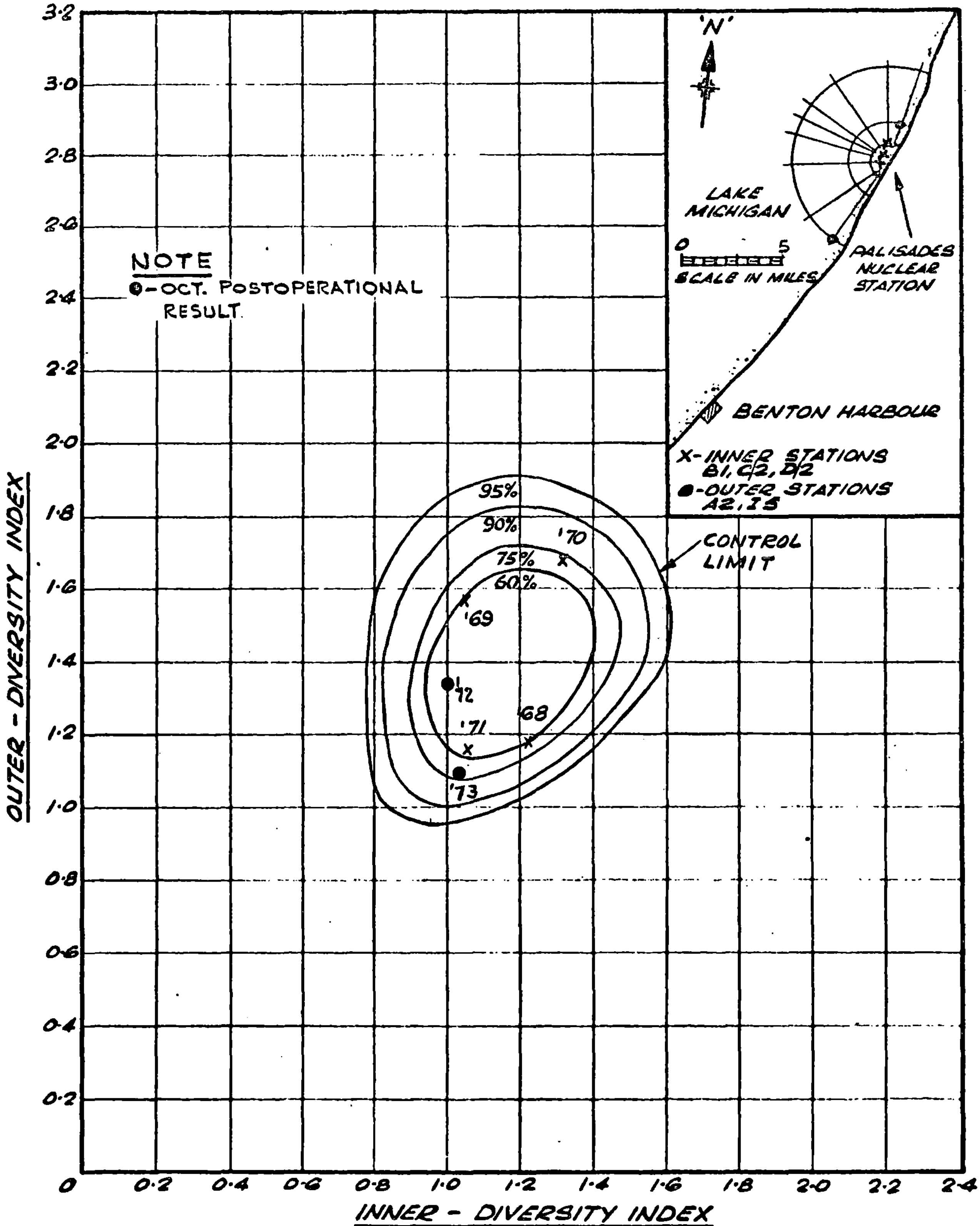
CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN. 12/73 DWG NO A 2048-10	FIG. C-76A

TRANSLAR 003



BENTHOS DIVERSITY – DEPTHS LESS THAN 20 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

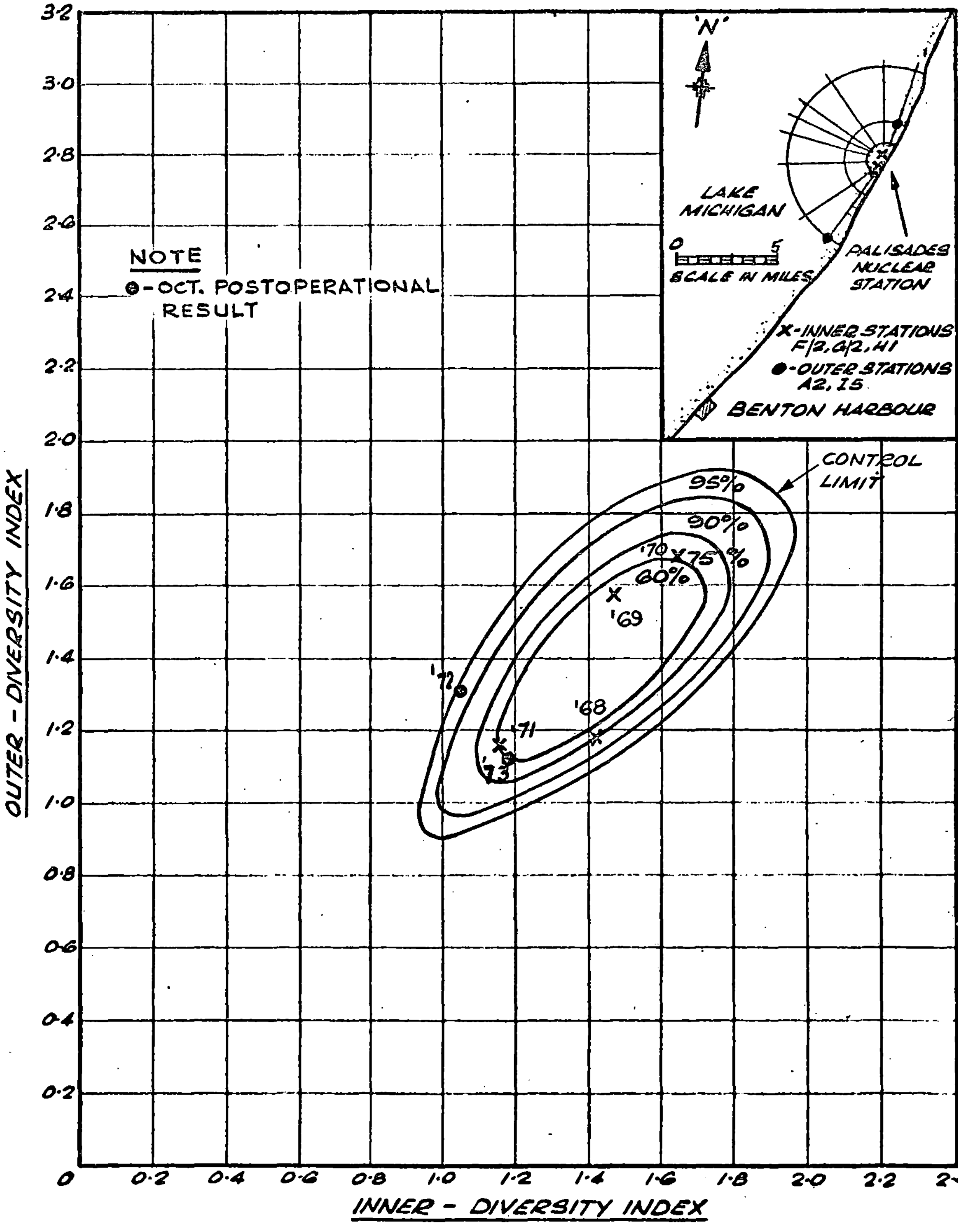
CONSUMERS POWER COMPANY JACKSON – MICHIGAN	BEAK	BY PAC / DATE 1 AUG 73 DWG NO A 2048 - 60	FIG. C-77A



BENTHOS DIVERSITY - NORTH QUADRANT - DEPTH 20-30 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 14/73 DWG NO A 2048-26	FIG. C-78A

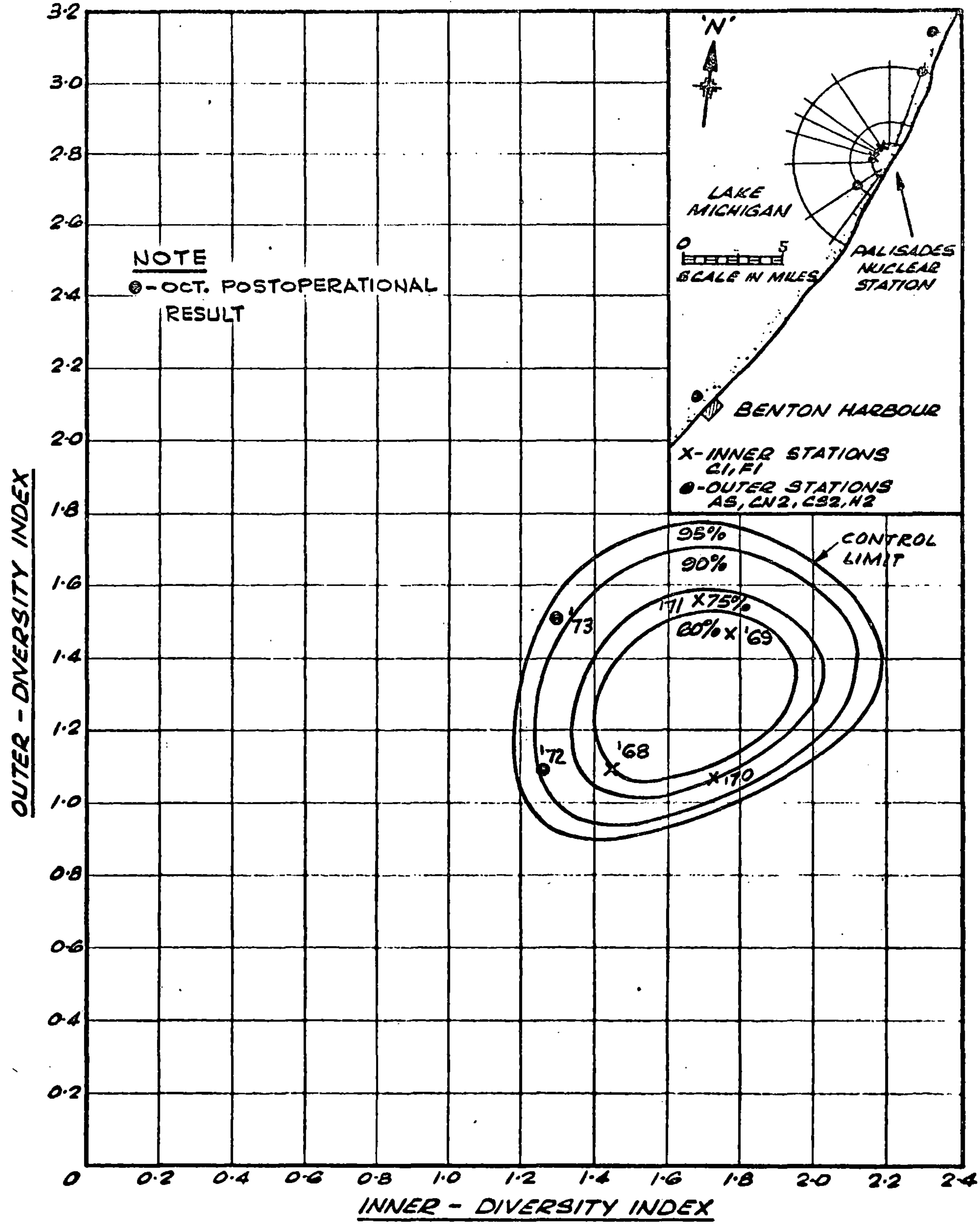
TRANSLAR 003



BENTHOS DIVERSITY - SOUTH QUADRANT - DEPTH 20-30 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 14/73 DWG NO A 2048 - 27	FIG. C-79A

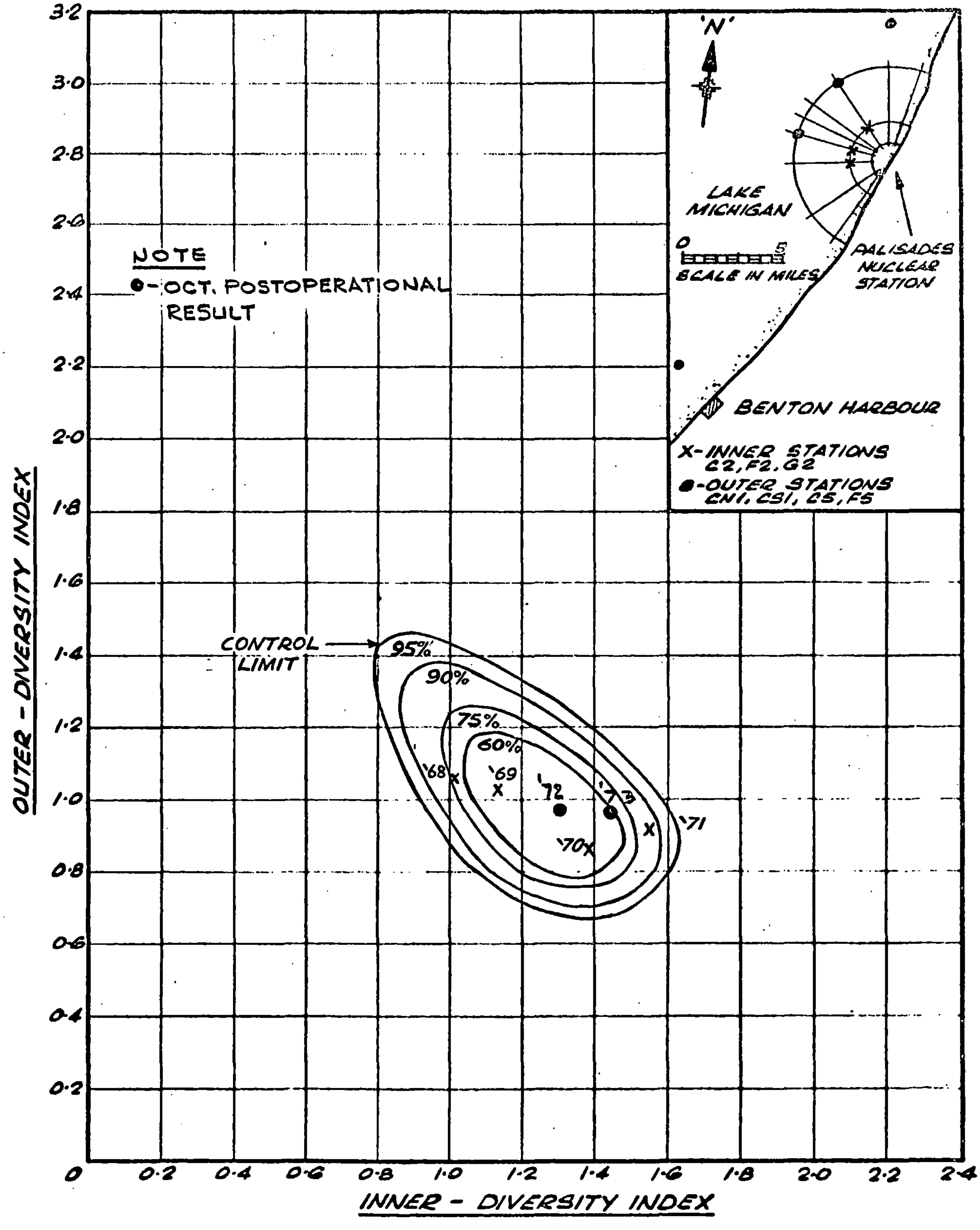
TRANSLAR 003



BENTHOS DIVERSITY - DEPTH 30-50 FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN 12/73 DWG NO A 2048-28	FIG. C-80A

TRANSLAR 003



BENTHOS DIVERSITY - DEPTH GREATER THAN 50FT
OCTOBER BIVARIATE CONTROL CHART
PREOPERATIONAL PERIOD 1968-71
LAKE MICHIGAN NEAR PALISADES, MICHIGAN

CONSUMERS POWER COMPANY JACKSON - MICHIGAN	BEAK	BY RCD DATE JAN. 12/73 DWG NO A 2048 - 29	FIG. C-81A

TRANSLAR 003

PRE- AND POST-OPERATIONAL BIOMASS DETERMINATIONS ON AMPHIPODS AND OLIGOCHAETE SAMPLES

A statistical analysis of the biomass of amphipods at the five stations composing the south quadrant chart was conducted to determine whether populations within the area of the plume were exhibiting an overall decrease in size as well as numbers.

The variances were large at all the stations except G/2 and the F test gave apparent significant differences between the populations. The modified 't' test[1] indicated that there were no significant differences between the means of the biomass of the pre-operational and post-operational amphipod populations at any of the five stations (Table Ca-1A).

Fixatives[2] cause benthic organisms to lose weight, especially during the first month. The intent of this study was not to determine actual live biomass, but just to compare biomass between surveys. For this study, it was assumed that as the majority of weight loss occurred in the first month after fixing, and the biomass determinations for comparisons between surveys were made after that time, the comparisons would be valid.

Table Ca-1A: Comparison of Pre- and Post-Operational Amphipod Biomass

STATION	PRE-OPERATIONAL			POST-OPERATIONAL			SIGNIFICANCE TESTS			
	$\bar{x}$	s^2	n	$\bar{x}$	s^2	n	't'		F	
F/2	0.276	0.084	3	0.016	0.0004	2	3.105	NS	210.0	S
G/2	0.012	0.0001	3	0.011	0.0001	2	0.111	NS	1.0	NS
H-1	0.144	0.055	4	0.017	1×10^{-6}	2	3.182	NS	55,000.0	S
A-2	0.049	0.002	4	0.0006	4×10^{-7}	2	2.181	NS	5,000.0	S
1-5	0.625	0.295	4	0.011	2×10^{-5}	3	2.274	NS	14,750.0	S

n = number of samples

A steady drop in density had occurred in the amphipod populations at the 30 to 50 foot depth range since the initiation of the study. To determine whether the condition of the organisms was also on the decline, biomass measurements were made on some of the pre- and post-operational samples. When the variances about the pre- and post-operational means were analyzed using the F test, they were not found to be significant (Table Ca-2A). The amphipod biomass at Station C-1, where the largest density changes had occurred, was studied, but there was no significant difference in biomass between the two time periods (Table Ca-3A). The change in percent organic carbon showed no direct relationship with the amphipod density changes (Table Ca-4A).

Lellak[3] could show no correlation between population densities and the organic carbon content of the sediments. Pontoporeia hoyi is thought to be an omnivorous form consuming benthic algae, bacteria and small benthic invertebrates. Other investigators[4] showed a preference of P. hoyi for organic sediments, and Marzolf showed a direct relationship between bacterial populations in the sediments and population densities of P. hoyi. Further study would have to be done with the sediments to investigate the bacterial content, but this did not lie within the scope of the project. Like Lellak, BEAK was unable to find a correlation between the results of sediment analysis and P. hoyi population densities.

Table Ca-2A: Comparison of pre- (1971) and post- (1973) operational amphipod densities at the 30 to 50 foot level

YEAR	$\bar{x}$	S	S^2	SIGNIFICANCE TESTS F		't'	
1971	44.36	49.67	2,467.10	2.43	NS	0.02	NS
1973	28.45	31.8	1,011.24				

$p = 0.05$ for 5 degrees of freedom

Table Ca-3A: Comparison of pre- and post-operational amphipod density at Station C-1

STATION	PRE-OPERATIONAL		POST-OPERATIONAL		SIGNIFICANCE TESTS			
	$\bar{x}$	S^2	$\bar{x}$	S^2	F		't'	
C-1	1.949	2.359	0.352	0.038	62.018	NS	0.947	NS

Table Ca-4A: Percent organic carbon and amphipod density at stations with depth of 30 to 50 feet for October 1971 and 1973

STATION	PERCENT ORGANIC CARBON		OCTOBER AMPHIPOD DENSITY (Avg/sq ft)	
	1971	1973	1971	1973
C-1	0.38	0.37	31.5	12.3
F-1	2.03	0.43	54.4	43.8
A-5	1.37	0.23	22.8	10.4
CN2	0.95	0.30	8.0	11.7
CS2	0.37	1.01	9.8	5.5
H-2	0.51	0.59	139.7	87.0

To determine whether the condition factor of the oligochaetes at the 20 to 30 foot depth stations had increased with the density, biomass measurements were done on some of the samples comparing pre- and post-operational samples. Sediment changes had occurred at some of these stations, with a higher proportion of silt being present in 1973. Analysis of variance about the mean using the F test and a study of the differences between biomass means using Students 't' test indicated that there was no significant difference between the June biomass of the two groups at the Inner stations F/2, G/2 and H-1, and at the Outer station A-2 (Table Ca-5A). At F/2 and 1-5, there were large variances between the biomass of the replicate samples at each station, giving an apparent significant difference between the pre- and post-operational samples, but using a modified 't' test, the differences between the means of the oligochaete biomass were not significantly different. Any apparent differences were caused by the non-random distribution of the oligochaetes, which is a known natural phenomenon in oligochaete populations. The large variances giving a significant F test seem to point to the need to use a greater number of replicate samples to determine the distribution of the clumps of oligochaetes, the numbers of oligochaetes in the clumps, and the species composition. Even the original six replicates were probably not sufficient for these organisms, especially when they are of major concern and are known not to be randomly distributed.

Table Ca-5A: Oligochaete biomass, June 20 to 30 foot stations, south of discharge

STATION	PRE-OPERATIONAL			POST-OPERATIONAL			SIGNIFICANCE TESTS			
	$\bar{x}$	s^2	n	$\bar{x}$	s^2	n	't'		F	
A-2	28.93	76.38	3	53.33	653.31	3	1.56	NS	8.55	NS
G/2	19.92	119.46	3	39.56	116.64	2	0.18	NS	1.02	NS
H-1	4.49	21.99	2	45.05	2,170.6	2	1.22	NS	98.70	NS
F/2	22.18	54.90	3	115.08	7,848.18	3	1.81	NS	142.95	S
1-5	30.68	598.29	3	183.39	65,705.06	3	1.02	NS	109.82	S

$\alpha = 0.05$

CONCLUSIONS

Analysis of some of the pre-operational and post-operational samples of oligochaetes and amphipods to compare biomass indicated that no changes had occurred in the condition of the organisms. The samples studied were from stations where density had shown a persistent low from pre-operational levels since the power plant began operations.

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2. Howmiller, Richard P., 1972. Effects of preservatives on weight of some common macrobenthic invertebrates. Trans. Amer. Fish Soc. 101 (4): 743-746.

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4. Kidd, Charles C., 1970. Benton Harbor power plant limnological studies Part VI. Pontoporeia affinis (Crustacea, Amphipoda) as a monitor of radionuclides released to Lake Michigan. Great Lakes Research Div. Univ. Michigan Special Report No. 44.

Key to Data Locations - Fish

Impingement Data

1. January 23-June 30, 1972 - Special Report #4 to AEC
2. July 1-December 31, 1972 - Semiannual Operations Report #4
3. January 1-June 30, 1973 - Semiannual Operations Report #5
4. July 1-October 25, 1973 - Semiannual Operations Report #6

Seine, Trawl and Gill Net Data

1. DNR 1969 and 1970 - Appendix C, Supplemental Information on Environmental Impact of Palisades Nuclear Plant.
2. BSF&W October and December, 1971 - Special Report #4 to AEC
3. BSF&W April and May, 1972 - Special Report #4 to AEC
4. CPCo May and June, 1972 - Special Report #4 to AEC
5. CPCo July and August, 1972 - Semiannual Operations Report #4
6. DNR June, August and October, 1972 - Semiannual Operations Report #4
7. CPCo January through June, 1973 - Semiannual Operations Report #5
8. DNR May and June, 1973 - Semiannual Operations Report #5
9. CPCo July, August, September and October, 1973 - Semiannual Operations Report #6
10. DNR August, 1973 - Semiannual Operations Report #6
11. DNR Final Report, 1968-1974 - Semiannual Operations Report #8

Egg and Larvae Entrainment Data

1. May 16-June 30, 1972 - Special Report #4 to AEC
2. July 1-December 29, 1972 - Semiannual Operations Report #4
3. March 21-June 28, 1973 - Semiannual Operations Report #5
4. July 2-October 17, 1973 - Semiannual Operations Report #6

Other Data

1. BSF&W Fry collections; cruises III through VIII and XI; April through October 1972 - Semiannual Operations Report #4

Key to Data Locations - Fish

Impingement Data

1. January 23-June 30, 1972 - Special Report #4 to AEC
2. July 1-December 31, 1972 - Semiannual Operations Report #4
3. January 1-June 30, 1973 - Semiannual Operations Report #5
4. July 1-October 25, 1973 - Semiannual Operations Report #6

Seine, Trawl and Gill Net Data

1. DNR 1969 and 1970 - Appendix C, Supplemental Information on Environmental Impact of Palisades Nuclear Plant.
2. BSF&W October and December, 1971 - Special Report #4 to AEC
3. BSF&W April and May, 1972 - Special Report #4 to AEC
4. CPCo May and June, 1972 - Special Report #4 to AEC
5. CPCo July and August, 1972 - Semiannual Operations Report #4
6. DNR June, August and October, 1972 - Semiannual Operations Report #4
7. CPCo January through June, 1973 - Semiannual Operations Report #5
8. DNR May and June, 1973 - Semiannual Operations Report #5
9. CPCo July, August, September and October, 1973 - Semiannual Operations Report #6
10. DNR August, 1973 - Semiannual Operations Report #6
11. DNR Final Report, 1968-1974 - Semiannual Operations Report #8

Egg and Larvae Entrainment Data

1. May 16-June 30, 1972 - Special Report #4 to AEC
2. July 1-December 29, 1972 - Semiannual Operations Report #4
3. March 21-June 28, 1973 - Semiannual Operations Report #5
4. July 2-October 17, 1973 - Semiannual Operations Report #6

Other Data

1. BSF&W Fry collections; cruises III through VIII and XI; April through October 1972 - Semiannual Operations Report #4

Table D-1A Summary of fish caught in gill nets
May - October, 1968-1973
(Michigan Department of Natural Resources)

SPECIES	PERIOD				TOTAL	% TOTAL
	May*	June	Aug.	Oct.**		
Alewife	2,956	4,314	446	231	7,947	53.3
Yellow perch	107	1,846	2,976	1,049	5,978	40.1
Longnose sucker	218	86	101	62	467	3.1
White sucker	37	38	49	61	185	1.2
Bloater	3	80	25	4	112	0.7
Smelt	17	5	18	22	62	0.4
Lake trout	16	15	7	8	46	0.3
Coho salmon	4	11	-	6	21	0.1
Chinook salmon	1	-	3	1	5	<0.1
Channel catfish	-	1	12	5	18	0.1
Brown bullhead	1	-	-	-	1	<0.1
Carp	-	-	8	6	14	<0.1
Burbot	-	1	2	2	5	<0.1
Golden redhorse	3	-	2	6	11	<0.1
Northern pike	-	-	3	5	8	<0.1
Round whitefish	3	-	1	2	6	<0.1
Lake sturgeon	-	-	-	1	1	<0.1
Gizzard shad	-	-	-	1	1	<0.1
Brown trout	3	2	-	-	5	<0.1
Lake herring	4	-	-	-	4	<0.1
TOTAL	3,373	6,399	3,653	1,472	14,897	

* Not fished in 1971, 1972
** Not fished in 1973

Table D-2A Number of fish per 100 lineal feet of beach seined both day and night at Van Buren State Park in May 1970 and 1973 *

(Numbers in parentheses are total number caught)

	Day	Night	
Date	4/9/73	5/14/70	5/7/73
Water temperature (F)	57	46	54
Lineal feet seined	800	420	800
Spottail shiner	30.6	36.2	8.4
Longnose dace	....	55.6	1.1
Alewife (adult)	8.0+	553.6	8.0+
Alewife (yearling)	....	10.6	....
Sculpin	....	(1)	....
Black bullhead	....	(1)	....
Chinook salmon	....	(1)	....
Trout-perch	....	1.7	1.1
Rainbow trout	1.1	....	1.9
Brown trout	0.3	....	0.3
Smelt (adult)	....	....	12.9
Carp (adult)	....	....	(1)
Largemouth bass	....	....	(1)

* Sampling by Michigan Department of Natural Resources

Table D-3A. Number of fish per 100 lineal feet of beach seined both day and night at Van Buren State Park in June 1969-1973 *

(Numbers in parentheses are total number caught)

	Day					Night			
	1969	1970	1971	1972	1973	1970	1971	1972	1973
Date	6/25	6/22	6/16	6/15	6/13	6/22	6/16	6/13	6/11
Water temperature (F)	56	65	69	69	64	67	69	64	73
Lineal feet seined	1200	900	1000	550	450	900	1000	550	1050
Spottail shiner	19.3	0.9	40.7	36.7	10.0	91.0	43.6	106.2	18.3
Longnose dace	3.8	12.7	3.7	5.3	7.8	11.7	10.2	16.0	0.6
Trout-perch	...	(1)	...	...	...	8.4	4.1	(1)	0.2
Coho salmon	...	...	...	...	...	...	(2)	...	...
Brown trout	...	...	...	2.2	0.3	...	...	...	...
Lake trout	(2)	...	(2)	...	...	...	...	...	...
Chinook salmon	(3)	0.7	(2)	1.8	7.6	...	...	...	(1)
Rainbow trout	...	...	...	(1)	...	...	...	...	(1)
Alewife (adult)	(1)	...	...	...	(1)	43.9	0.9	33.5	17.2
(yearling)	0.3	...	12.9	0.9	25.1	0.2	(1)	0.5	5.5
Perch	...	...	5.6	...	(1)	0.4	0.7	...	0.3
Carp (adult)	...	...	...	...	...	...	...	...	1.6
Bluegill	(1)	...	...	...	...	(2)	...	...	(1)
Golden redhorse (adult)	...	...	...	...	...	...	...	...	(1)
Johnny darter	0.3	...	0.3	...	...	(1)	...	...	...
Emerald shiner	(2)	...	...	...	...	...	...	...	...
Bloater	(2)	...	...	...	...	...	...	...	...
Sculpin	(1)	...	...	...	...	...	...	(2)	...
Grass pickerel	...	(2)	...	...	...	(1)	...	...	...
Black bullhead	...	...	...	...	...	(1)	...	(1)	...
Smelt	...	...	...	(2)	...	...	...	...	...
Pumpkinseed	...	...	...	...	...	...	...	(1)	...
Creek chub	...	...	...	...	...	...	...	(1)	...

* Sampling by Michigan Department of Natural Resources.

Table D-4A Number of fish per 100 lineal feet of beach seined both day and night at Van Buren State Park in August 1969-1973 **

(Numbers in parentheses are total number caught)

	Day				Night				
	1969	1970	1971	1972	1969	1970	1971	1972	1973
Date	8/4	8/24	8/17	8/16	8/4	8/24	8/17	8/16	8/13
Water temperature (F)	80	76	66	65	73	71	66	72	78
Lineal feet seined	900	820	1020	1045	600	820	1020	1045	1200
Spottail shiner	0.7	(1)	0.7	13.2	9.7	0.9	1.0	8.0	14.0
Longnose dace	2.1	1.6	(1)	1.3	11.7	4.8	(2)	1.3	0.5
Alewife (adult)	(1)	...	...	...	(1)	(3)	2.4	(4)	(3)
Alewife (yearling)	...	...	...	...	...	4.1	...	...	...
Alewife (young)	418.0	2.0+	*	*	...	5.1	*	...	8.3+
Common shiner	...	(2)	...	...	...	...	...	...	...
Yellow perch (young)	...	...	2.6	...	...	...	...	...	...
(yearling)	...	...	(1)	...	13.5	(3)	...	...	1.5
(adult)	...	...	...	...	...	...	4.4	(3)	...
Brown trout	...	...	...	(1)	...	...	...	(2)	...
Trout-perch	...	...	...	...	2.5	6.0	(1)	1.1	0.8
White sucker	...	...	...	...	(1)	...	...	...	...
Sculpin	...	...	...	...	...	(1)	...	...	...
Black bullhead	...	...	...	...	...	(2)	...	...	...
Smelt	...	...	...	...	...	(2)	...	...	...
Carp (adult)	...	...	...	...	...	(1)	...	...	(1)
Quillback (adult)	...	...	...	...	...	(2)	...	(1)	(1)
Smallmouth bass (adult)	...	...	...	...	...	(2)	...	...	(1)
Rainbow trout	...	...	...	...	...	...	...	0.5	...
Northern pike	...	...	...	...	...	...	...	...	(1)
Bluegill (adult)	...	...	...	...	...	...	...	...	(1)

* Numerous

** Sampling by Michigan Department of Natural Resources.

Table D-5A Number of fish per 100 lineal feet of beach seined both day and night at Van Buren State Park in October 1969-1972**

(Numbers in parentheses are total number caught)

	Day			Night		
	1969	1970	1972	1969	1970	1972
Date	10/2	10/12	10/2	10/1	10/12	10/4
Water temperature(F)	64	59	59	64	59	62
Lineal feet seined	1200	840	780	1260	840	780
Spottail shiner	1.1	....	....	....	....	14.1
Longnose dace	12.0	9.4	1.1	....	....	6.8
Alewife (adult)	(1)	....	....	....	....	(1)
Alewife (young)	(1)	13.7+	*	....	....	50.1
White sucker	(1)	....	....	....	....	....
White sucker (adult)	....	(1)	....	....	....	....
Smelt (yearling)	(1)	....	(2)	....	....	....
Smelt (young)	(2)	....	....	....	....	....
Trout-perch	....	....	....	....	....	2.0
Rainbow trout	....	....	....	....	....	(1)
Longnose gar (adult)	....	....	....	....	....	(1)

* Numerous
** Sampling by Michigan Department of Natural Resources.

Table D-6A Species composition and total numbers of fish captured in trawl tows made in 1969 and 1972 in the vicinity of the Palisades nuclear power plant[1] **

Species	39-foot trawl					15-foot trawl
	May 3, 1969		July 25, 1969			August 17, 1972
	Depth (feet)		Depth (feet)			Depth (feet)
	24	42	18	42	72	10-15
Smelt (adult)*	1	52	...	17	89	...
Smelt (yearling)	264	86	...	...	...	...
Smelt (young)	...	...	...	...	...	numerous
Alewife (adult)	...	150	67	195	190	35
Spottail shiner	1	26	27	3	...	5
Trout-perch	...	18	...	254	...	...
Bloater	...	...	1	21	72	...
Yellow perch	...	...	1	...	...	...
Lake herring	...	...	...	...	...	1

[1] In 1969, one 5-minute tow was made at each depth under 50 feet; on 10-minute tow at 72 feet. Five 5-minute tows were made in 1972.

* Fish over 100 mm (4.0 inches) in length.

** Sampling by Michigan Department of Natural Resources.

Table D-7A Percent age composition of yellow perch in monthly gill net catches near the Palisades Power Plant, 1968-1973

(Number in parentheses is number of fish)

Month and year	Age-group I	II	III	IV	V	VI	VII	VIII	Total number caught
May									
1968	..	22	30	22	13	9	..	(1)*	23
1969	..	(3)	(3)	(2)	(2)	(1)	..	..	11
1970	..	(1)	47	21	16	..	11	..	17
1973	..	9	23	29	16	9	..	..	56
June									
1968	..	54	43	(1)	..	2	..	..	94
1969	..	12	40	25	..	5	3	2	161
1970	..	6	35	49	8	1	..	1	384
1971	..	37	22	37	4	(1)	..	..	339
1972	..	10	64	16	10	..	..	..	222
1973	..	3	5	20	4	1	..	..	646
August									
1968	..	70	17	(1)	(1)	7	..	..	30
1969	29	23	27	21	..	..	..	..	473
1970	31	27	19	21	2	..	..	..	595
1971	1	81	11	5	1	1	..	..	380
1972	(1)	45	50	3	1	..	..	..	850
1973	3	5	46	43	4	(2)	..	..	648
October									
1968	17	31	35	10	2	4	..	..	116
1969	(1)	(5)	(5)	(2)	..	..	..	..	13
1970	55	15	19	11	..	..	..	..	522
1971	15	73	10	1	1	..	..	..	314
1972	16	17	41	20	5	(1)	..	..	76

* XI

Data collected by Michigan Department of Natural Resources

Table D-8A Percentage age composition of yellow perch in gill net catches near the Palisades Power Plant for the years 1968-1973[1]

(tr = trace or < 1.0%)

Age group	Year 1968	1969	1970	1971	1972	1973
I	8	22	31	5	1	1
II	43	21	17	64	37	4
III	35	32	24	14	52	31
IV	7	24	24	14	7	54
V	2	tr	3	2	3	7
VI	4	1	tr	1	tr	1
VII-IX	tr	1	tr	..	..	..
Total number caught	262	631	1,518	1,033	1,148	1,350

[1] Underlined values pertain to the 1969 year class.

Data collected by Michigan Department of Natural Resources.

Table D-9A Average length (inches) at capture and calculated weights for male yellow perch of five age groups captured near the Palisades Power Plant before (1970-1971) and after 1972-1973) release of thermal discharges

Age group and year of capture	June 12-14			August 16-17			October 4-6		
	Length	Wt (oz)	Number of fish	Length	Wt (oz)	Number of fish	Length	Wt (oz)	Number of fish
I*									
1970-71	3.2	....	18	5.0	....	20	5.8	....	10
1973	....	....	..	5.3	....	21	....	....	..
II									
1970-71	6.3	1.6	22	7.1	2.3	18	7.9	3.3	18
1972	6.1	1.4	10	7.7	3.0	5	7.5	2.8	2
1973	6.1	1.4	10	7.1	2.3	3	....	....	..
III									
1970-71	7.8	3.2	7	9.2	5.4	8	9.4	5.8	6
1972	7.9	3.3	21	8.2	3.7	13	8.9	4.9	3
1973	7.5	2.8	5	8.3	3.9	35	....	....	..
IV									
1970-71	9.2	5.4	9	9.7	6.5	9	....	....	..
1972	9.2	5.4	5	....	....	..	....	....	..
1973	8.5	4.2	35	9.2	5.4	32	....	....	..
V									
1970-71	9.6	6.2	4	9.9	6.9	3	....	....	..
1972	10.2	7.6	5	....	....	..	10.9	9.4	1
1973	9.1	5.2	2	10.3	7.8	3	....	....	..

* Sex not determined.

Data collected by Michigan Department of Natural Resources.

Table D-10A Average length (inches) at capture and calculated weights for female yellow perch of five age groups captured near the Palisades Power Plant before (1970-1971) and after (1972-1973) release of thermal discharges

Age group and year of capture	June 12-14			August 16-17			October 4-6		
	Length	Wt (oz)	Number of fish	Length	Wt (oz)	Number of fish	Length	Wt (oz)	Number of fish
I*									
1970-71	3.2	....	18	5.0	....	20	5.8	....	10
1973	....	....	..	5.3	....	21	....	....	..
II									
1970-71	6.9	2.1	20	8.1	3.6	19	8.7	4.6	23
1972	6.4	1.7	12	7.2	2.5	9	8.4	4.0	11
1973	6.3	1.6	12	....	....	..	....	....	..
III									
1970-71	8.9	4.9	28	10.2	7.6	19	11.2	10.3	2
1972	9.1	5.2	43	9.6	6.2	43	10.0	7.1	26
1973	8.1	3.6	22	9.0	5.1	12	....	....	..
IV									
1970-71	10.2	7.6	25	11.4	10.9	9	....	....	..
1972	11.2	10.3	23	11.6	11.5	14	11.9	12.5	14
1973	10.2	7.6	93	10.8	9.1	31	....	....	..
V									
1972	11.7	11.8	10	12.5	14.7	11	12.7	15.4	4
1973	11.8	12.2	27	12.2	13.5	4	....	....	..

* Sex not determined.

Data collected by Michigan Department of Natural Resources.

Table D-11A Instantaneous rates of perch growth for the periods mid-June to mid-August and mid-June to October 4 in Lake Michigan near the Palisades Power Plant

Age group	Year of capture	June-August		June-October	
		Males	Females	Males	Females
II	1970-71	.37	.54	...	.79
	1972	.76	.39	...	.86
	1973	.50	...	...	...
III	1970-71	.53	.44	.60	.74
	1972	.11	.18	.48	.37
	1973	.28	.35	...	...
IV	1970-71	.18	.36	...	...
	1972	.55	.11	...	.19
	1973	.25	.18	...	...
V	1972	...	.22	...	.27
	1973	...	.10	...	...

Data collected by Michigan Department of Natural Resources.

TABLE D-12A Number of fish collected by seining during daytime 1972-1973

SPECIES	ZONES: 1		2		3		4		5	
YEARS:	1972	1973	1972	1973	1972	1973	1972	1973	1972	1973
Alewife - A	47	607	717	71	26	137	1,786	88	374	203
- Y	1,619		16	4	7,200	691	390	1,328	82	8
Chinook		3		28				21		28
Lake trout - Y							1			
Coho salmon	17		164	8	1	12	5		2	
Steelhead				20		111		2		5
Brown trout	6		4	4		32		5	1	2
Smelt - A		22	1	8		32		21	2	3
- Y		7		6		5		6		18
Carp	1		4				81	2		
Spottail shiner - A	310	257	182	154	224	119	842	102	151	174
- Y	50	113	40	33	5	1,549		35	15	9
River chub				1						
Fathead minnow				1				1		
Longnose dace				4				4		2
Emerald shiner						4		1		1

Table D-12A (continued)

	ZONES									
	1		2		3		4		5	
SPECIES YEARS:	1972	1973	1972	1973	1972	1973	1972	1973	1972	1973
Common shiner		9		10				2		
Longnose sucker			1						1	
White sucker			1							
Northern pike		1		14						
Trout-perch		1					2			2
Bluegill	3		1			9	6	29		
Pumpkinseed						1	1	8		
Black crappie						1		2		
Johnny darter			3	1		1		1	1	1
Perch - Y		2		263		39				
TOTALS	2,053	1,022	1,134	630	7,456	2,743	3,114	1,658	629	456

A = Adults
Y = Young-of-the-year and yearlings

Table D-13A Total number of fish collected by seining during nighttime 1972-1973

	ZONES									
	1		2		3		4		5	
SPECIES YEARS:	1972	1973	1972	1973	1972	1973	1972	1973	1972	1973
Alewife - A	240	25		528	500	20	2,074	501	1	1,058
- Y	3	10	24				28	35	12	
Chinook				1						1
Coho salmon	16		23				5		4	
Steelhead	1		1	6						1
Brown trout	5		1	1		1				1
Smelt - A	4		1	1						
Carp				2		20	43	12		2
Spottail shiner - A	43	55	6	77	20	43	1,445	73	7	164
- Y			9	6		38		13	17	1
Spotfin shiner							300			
Longnose dace						1				6
Emerald shiner								3		1
Longnose sucker							2		3	
Northern pike	1									1

Table D-13A(continued)

SPECIES	ZONES: 1		2		3		4		5	
YEARS:	1972	1973	1972	1973	1972	1973	1972	1973	1972	1973
Trout-perch						1	3	3	1	
Bluegill						5	16			
Pumpkinseed					1	1	11			
Smallmouth bass							1			
Black crappie						1	1			1
Johnny darter		1		1		4	1		2	2
Perch - A	1						51			
TOTALS	314	91	65	622	521	135	3,983	640	47	1,233

A = Adults
Y = Young-of-the-year and yearlings

Table D-14A Total number of fish collected by trawling for 1972-1973

SPECIES	HEATED DISCHARGE				NON-HEATED DISCHARGE			
ZONES:	1	2	3	4	1	2	3	4
Alewife - A	717	279	2,003	288	134	150	63	200
- Y	13	20	13	6	2	80	89	19
Steelhead		1					2	
Brown trout			1					
Bloater	2	11	10	2				
Coho salmon				2				
Smelt - A	40	11	47	42	113	123	62	97
- Y	3		2	6	443	335	546	109
Longnose sucker		8						2
White sucker					5	5	2	4
Spottail shiner	4	262	59	99	28	154	122	70
Trout-perch		7				6	3	3
Northern pike			1		1	2	2	2
Perch - A	2	532	92	86	39	139	19	38
- Y					4	109	17	11
Channel catfish		1		1				
Johnny darter	2		1	1				
Carp	2		4					
Slimy sculpin	1	2		2				
TOTALS	786	1,134	2,233	535	769	1,103	927	557

A = Adult
Y = Young-of-the-year and yearlings

Table D-15A Total number of fish collected by perpendicular trawling hauls for 1972-1973

SPECIES	HEATED DISCHARGE				NON-HEATED DISCHARGE			
ZONES:	1	2	3	4	1	2	3	4
Alewife - A	94	140	1,562	193	138	191	646	1
- Y					11	10	17	
Bloater		2	1					
Smelt - A	17	13	9	24		5		
- Y	2				5		1	
Longnose sucker	1	4	1					
Spottail shiner	3	5	18	15	9	14	92	
Perch - A	63	22	222	18		6	18	
Trout-perch				13	1			
Carp						1		3
Johnny darter							2	
Slimy sculpin								1
TOTALS	180	186	1,813	263	164	227	776	5

A = Adult
Y = Young-of-the-year and yearlings

TABLE D-16A

Total number of fish collected from the traveling screens at the Palisades Nuclear Power Plant.

Species		1/23/72-7/1/72	7/1/72-12/29/72	12/30/72-6/29/73	6/30/73-10/25/73
Marine lamprey		-	-	1	-
Gizzard shad		-	4	2	3
Alewife	Adult Young	(14,049)	16,190 41,290	287,882 175	22,713 1,100
Cisco		-	-	3	-
Steelhead		-	-	5	-
Coho salmon		13	5	5	3
Chinook salmon		1	2	16	10
Lake chub		18	-	3	-
Lake trout		-	3	56	9
Lake whitefish		-	-	8	20
Round whitefish		-	-	1	-
Brown trout		-	1	-	-
Bloater		199	139	6	177
Smelt	Adult Young	598	288	4,616 525	1,257 349
Northern pike		-	2	3	13
Central mudminnow		-	-	1	-
Carp		14	3	-	-
Longnose dace		3	-	2	-
Spottail shiner		3,955	19,717	21,095	2,130
River chub		-	-	2	-
Northern redhorse		-	-	1	-
White sucker		5	169	189	32
Longnose sucker		64	373	603	254
Channel catfish		12	89	67	-
Yellow bullhead		-	1	1	-
Black bullhead		25	10	39	2
Trout-perch		543	610	1,425	907
Burbot		46	136	287	44
Nine-spine stickleback		231	17	157	4
Slimy sculpin		8,005	1,011	171,146	41
Rock bass		1	-	-	-
Pumpkinseed		-	2	-	-
Bluegill		1	1	3	-
Perch	Adult Young	(6,305)	4,718 593	10,676 357	134 5,674
Johnny darter		10	1	13	-
Sp[illegible] fin shiner		-	1	-	-
Sucker (undefined)		45	-	-	-
Log perch		-	-	-	1
Total		34,368	85,376	499,311	34,877

TABLE D-17A

Total weight of fish collected from the traveling screens at the Palisades Nuclear Power Plant.

Species		5/16/72-7/1/72	7/1/72-12/29/72	12/30/72-6/29/73	6/30/73-10/25/73
Marine lamprey		-	-	-	-
Gizzard shad		-	-	-	<1
Alewife	Adult	1,056	1,302	23,026	1,825
	Young		275		
Cisco		-	-	2	-
Steelhead		-	-	7	-
Coho salmon		3	4	13	<1
Chinook salmon		-	14	9	4
Lake chub		-	-	1	-
Lake trout		2	7	36	46
Lake whitefish		-	-	13	4
Round whitefish		-	-	1	-
Brown trout		-	<1	-	-
Bloater		28	23	1	48
Smelt		18	22	325	62
Northern pike		-	3	1	10
Central mudminnow		-	-	-	-
Carp		-	28	-	-
Longnose dace		-	-	-	-
Spottail shiner		158	761	881	85
River chub		-	-	-	-
Northern redhorse		-	-	1	-
White sucker		6	258	312	49
Longnose sucker		60	358	869	327
Channel catfish		2	30	12	-
Yellow bullhead		-	<1	<1	-
Black bullhead		1	1	4	<1
Trout-perch		22	23	56	36
Burbot		29	225	449	56
Nine-spine stickleback		3	3	2	<1
Slimy sculpin		101	13	2,411	58
Rock bass		<1	-	-	-
Pumpkinseed		1	<1	-	-
Bluegill		<1	<1	<1	-
Perch		1,476	1,231	3,615	1,593
Johnny darter		<1	-	-	<1
Spotfin shiner		-	<1	-	-
Log perch		-	-	-	<1
Total		2,965	4,581	32,050	4,210

*Total may not add due to rounding.
Units are in Lbs.